The Effects of Natural Locomotion (Walk-in Place) on Presence, Avatar-Identification, and Cybersickness in VR

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Abstract

The terms immersion and presence are widely used today in the VR gaming industry as a measure of the success of a game (Brown and Cairns, 2004).So, it is essential to develop an understanding of how to maximize the sense of presence on virtual reality, and how to minimize to feelings of cybersickness that is experienced in VR (Weech et al., 2019) .In this paper, we will be attempting to measure cybersickness, avatar-identification, and sense of presence in the VR environment using subjective and objective measures. The subjective measures include multi-item questionnaires and the objective measurements include measuring the basic physiological function of the human body(blinking rate,pupil diameter, and heart rate). Unlike previous studies, this study will attempt to measure the long-term effects of VR experience, and we will attempt to study how the implementation of locomotion (walk in place) in the VR system affect presence, avatar-identification, and cybersickness in the long term. We present two studies where in the first study participants will be playing a modded Skyrim VR in four different conditions. In the second experiment, these participants will be playing the game for extended period of time (1 hour per day over one whole week) utilising the Natural locomotion (walk-in place) software in order to navigate and interact with the world of Skyrim. During these experiments we will be measuring heart rate, pupil diameter, and blink rate as objective measures. In addition to that, participants will be filling answering multi-items questionnaires in order to describe their experience in the virtual environment. At the end we will try to identify the relations between these three variables, and the ways in which physiological objective measurements correlate with presence in virtual reality.

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Chapter 1

Introduction

1.1Background

Current VR-Systems are so remarkable in terms of technological achievements, and these systems give users an immersive experience that is very clear and vivid (Munafo et al, 2016). VR facilitates a new medium for human-computer interaction in which the interface between human and computer is redefined. This medium of interaction enhances the user's ability to explore the virtual environment by making the users use a Head mounted display and use a data glove rather than using traditional screens and keyboards in order to interact with the environment. The VR system enhances the user's immersion in a computational environment (Regan. 1995), and in order for the VR experience to be effective, the scenario presented to the user must fulfil requirements that allow the user to be involved in the sensory experience capturing their attention overruling their physical reality in favour of the virtual reality (Silva et al., 2016). One of the main goals of VR is to allow the user to experience a sense of immersion in the virtual world, and previous studies have shown that immersion in virtual environments can be achieved through equipment that can display a verisimilar experience through HMD, spatial sound reproduction, realistic virtual graphics, interactions, and other realistic sensory mediators (Takatalo et al., 2008).

Another aim of virtual reality is utilizing the immersive equipment in order to generate a sense of presence in the individual that is navigating the virtual environment. Presence can be defined as the illusion of non-mediation toward the virtual experience or the subjective feeling of being there which means that the VR technology allows the user to temporarily perceive his interactions as independent of VR equipment as if he was touching, moving, seeing, and hearing from the virtual stimuli directly. Therefore, presence could be understood as result from the relationship between the quality of immersive experience and individual characteristics (Silva et al., 2016).

Despite the positive immersion experience that the user feels when engaged in virtual environment, reports show that this pleasurable experience transitions to discomfort, nausea, and disorientation (Boyd, 2014; Lewis, 2015). This problem is still acknowledged by the manufacturers who have tried to counter these problems without any success in finding any permanent solution. Such limitation is preventing these systems from widely spreading as they are supposed to (Lang, 2016).

The ultimate goal of the VR system is still unachievable which is providing an accurate real-life simulation that keep the user in a state of presence throughout the whole VR experience, and one of the main barriers that prevent reaching such goal is failing to keep the user in a state of presence consistently. Another barrier is the cybersickness that is usually accompanies the exposure to VR content. Therefore, in order to unlock the full potential of VR systems, researchers must understand and solve these barriers (Weech et al., 2019).

1.2 Project Structure and aims

In attempts to try and find solutions to the problem mentioned in the previous, we decided to conduct this study where we will be thoroughly investigating the presence status that VR users experience during VR sessions. Our project will include 3 important subjective measurements which are presence, cybersickness, and avatar-identification. We will be trying to investigate the changes in these measurements across different experimental conditions that we implement, and we will aim at finding how avatar-identification and cybersickness affect the state of presence that the user is experiencing throughout our experimentation.

In addition to that, we will also be recording some physiological objective measurements (heart rate, pupil diameter, blink rate), and we will try to find correlations between these objective measurements and the state of presence that the users experience in our study in order to enhance our understanding of “presence”.
In our attempt to enhance the state of presence that users experience during the virtual reality experience, we will be proposing a different way to interact with the hardware where players will not be using traditional controllers to navigate the world, instead, we will be implementing locomotion walk-in-place functionality where the users will have to physically move or run in place in order to move in the virtual world. We are hoping that the implementation of this new mechanic will

enhance the user's immersion and presence in the virtual world in the short-term and long-term.

As for the virtual world that our users will be interacting with, we decided to use a game called "SkyrimVR" which is a very popular and immersive open-world game.

1.3 Why Skyrim?

We decided to use Skyrim for this project because it was selected for this study because it was considered the winning game of the year by several publishers in 2011 for its gameplay and immersiveness (De Koven, 2013), and the game is still supported to this day by a community of modders that keep enhancing and improving the game features. The game is an open-world role-playing game, and its success lies in the epic scale of the world, interesting quests, interesting characters, freedom to roam the virtual world freely, and the endless opportunities for adventure. The game is beginner friendly and has a lot of features that keep players engaged throughout the experience for long hours. These features include: non-linear narratives, great storytelling, open-ended world, tools that the player can utilise throughout his journey that fit his playstyle and choices, different main and side narratives with different characters to interact and engage with, player choices that impact the world of the game, and customising skills and talents according to the player's preferences and needs (De Koven, 2013). In addition to all these features that Skyrim provides, we are adding additional mods to improve graphics, sounds, gameplay, and control which are all factors that have been proven to improve presence in virtual reality (Witmer and Singer,1998). Furthermore, we are implementing (Walk-in place) locomotion to allow the user to navigate the world while walking in place because we are predicting that such mechanic would reduce cybersickness and allow the user to sustain the sense of presence.

1.4 Project Novelty

After we conducted thorough research about different researchers that attempted to study the state of presence that users experience in virtual reality, we noticed that most of these researches focused on implementing different ways in which users interact with the hardware in order to improve the state of presence and decrease their cybersickness, and all of these researches focused only on the short-term effects that the utilisation of new movement mechanic had on presence where the whole experimentation only lasted a couple of hours. We believe that our experiment will be grander in scale and give deeper understanding of presence, cybersickness, and avatar-identification. First, our study will develop enhanced understanding of the personal traits and characteristics that affects presence. In addition to that, in our study, we will be conducting two experiments where one will focus on the short-term effect of implementing walk-in -place locomotion has on cybersickness, presence, and cybersickness. On the other hand, the second study will be conducted over 1-week period where users will participate in 1 hour gaming sessions each day using the walk-in place, and the aim here is to detect the changes in these three variables and the ways in which they interact with each other.

Our study will not only be limited to subjective measurement where we will also be tracking physiological objective measurements during both experiments to check for correlations between these measurements and the state of presence hoping to get a better understanding of how the change in these measurements affect presence and immersion.

In addition to that, we will be extracting the elements in the virtual world that seemed to enhance the state of presence over long-term periods. For all these reasons, we believe that our study will provide further understanding of the experience that the users experience in virtual reality, and our results could be utilised for more constrained future works in the field.

1.5 Research Questions

In this research, we will be attempting to answer the following question:

(RQ1) How do presence, cybersickness, and avatar-identification measurements change in virtual reality in the short- and long-term?

(RQ2) What is the relation between cybersickness, avatar-identification and presence?

(RQ3) How does the implementation of locomotion walk-in place functionality affect presence in the short- and long-term?

(RQ4) How do physiological objective measurements correlate with presence?

(RQ5) What elements of the virtual world affect the sense of presence in virtual reality?

(RQ6) How do personal characteristics and traits affect presence in virtual reality?

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Chapter 2

Related Work

2.1 Cybersickness

Cybersickness is defined as a constellation of symptoms of discomfort and malaise that are produced after VR experience. It is categorized as a form of induced motion sickness produced by the observation of visual motion, and its symptoms is similar to simulator sickness that is produced by vehicle simulators (Stanney et al., 1997). Cybersickness is still a controversial topic because while many experience cybersickness in VR, others appear to be robust to the symptoms (Weech et al., 2019). There are lots of factors that have been identified to cause cybersickness such as observed and expected sensory details (Rebenitsch and Owen, 2016), self-motion (McCauley and Sharkey, 1992), the quality of the visual display (Moss and Muth,2011), and gameplay experience (Gamito et al., 2008).

2.1.1 Theories Behind Motion Sickness

There are lots of theories that tried to analyse the reasons behind motion sickness. Most of these theories are based on qualitative analysis. It was very hard to quantify the severity and the degree of motion sickness that might occur in a specific circumstance or situation. All the theories acknowledged that the vestibular system plays a very critical role in inducing motion sickness. One of the theories says that motion sickness is caused by an excessively simulating the organs of balance. However, there was lots of controversy surrounding the involvement of otoliths or the semi-circular canals in the induction of motion sickness (Regan, 1995). Another theory was hypothesised by eye movement which argues that motion sickness is due to the person’s eye movement (Ebenholtz et al ,1994). However, it was counterargued by the fact that a person can still develop motion sickness from his/her eyes closing during movement (Aldaba and Moussavi, 2020). In addition to this theory, there is postural inability theory which states that motion sickness is caused by a person’s inability to maintain his or her balance (Stoffregen, 1991). This theory was counterargued by the fact that a person can still develop motion sickness from vertigo.

The most popular theory of motion sickness that was analysed and presented by James Reason (1974) is the sensory conflict theory. It is still widely accepted because the theories of eye movement and postural instability have been counter argued (Aldaba and Moussavi,2020). This theory offers lots of explanation about the common kind of motion sickness such as space sickness, car sickness, and simulation sickness. It argues that all the situations that lead to motion sickness are characterised by conditions where the signals transmitted by the visual system lead to conflict between the vestibular system and the non-vestibular position senses based on what we expect from lots of past experience. The conflict will fall into two main categories. The first category is that the information transmitted from the visual system and the vestibular system are incompatible with each other. The other category is that the information within the vestibular system are incompatible, for example the canals and the otolith provide incompatible or contradicting signals. In summary, the explanation of motion sickness relies heavily on the conflict of information received by the senses. There were also lots of development in this theory. For example, Treisman (1977) tried to explain the origin of vomiting reflex during motion sickness, and his study showed that the conflict in sensory input are interpreted as neurophysiological dysfunctions that are caused by cases of poisoning.

Based on these analyses, the VR immersion experience can be regarded as introducing sensory conflict because, similar to simulator sickness, the immersive VR will implement a conflict between the visual system and the vestibular system (Regan, 1995). Most of today’s VR systems, the movement is controlled by a hand glove or controller that allows the user to press button or gestures in order to navigate the virtual environment. This interaction will result in changes in the visual scenes, so the visual system interprets the information as body movement while vestibular system suggests a more static body position leading to sensory conflict. Another issue that arises from these systems is the display update lags. Such a problem might introduce sensory conflict for the user when between an action or movement and the result or change in visual scene becomes relatively high. The conflict arises in times difference between the actual physical movement that provides vestibular information and the movement of the visual field on the screen. Other issues that could cause sensory conflict for some users is the low resolution of display which varies from one system to the other.

2.1.2 Symptoms of Cybersickness

The effects of cybersickness can vary among the users of VR. The user may develop some symptoms related to gastrointestinal distress like burping, salivation, stomach awareness, and nausea. In addition to that, VR devices might cause visual distresses like difficulty having difficulty of focusing, headaches, and vertigo. Likewise, they may also suffer from vestibular distresses like dizziness and vertigo (Kennedy et al, 2010). Other physiological problems can include an increase in the rate of blinking and respiration (Dennison et al, 2016). These symptoms can distract and hinder a user's ability to perform a task in VR and immerse himself or herself in the VR environment. Since the frequency of occurrence of motion sickness was so high, there are lots of studies that tried to propose some novel solutions in order to remedy the sickness. These solutions were non-medical and included design of new software techniques and devices (Aldaba and Moussavi, 2020). Some of these treatments included simultaneous transcutaneous electrical nerve simulation to either posterior neck and distal to the right knee (Chu et al, 2013), or bilaterally on top of the sternocleidomastoid muscles (Galvez- Garcia et al, 2015). Although these treatments were effective in reducing motion sickness, the devices were hard to setup, and they may interfere with presence and immersion in the virtual reality. As a result, different solutions had to be implemented to optimize the VR experience.

2.1.3 Optimizing VR Experience

Studies showed that the variation in in varying latency compared to a constant latency is significantly increasing the motion sickness. Varying latency was derived from complex algorithms and computations and the execution time was longer than the time between the HMD updates (Pierre et al, 2015). In order to achieve better results, the computations should be executed at a shorter time, or they should be executed by a parallel processor to decrease motion sickness (Aldaba and Moussavi, 2020). Visual distress can also be decreased by programming a dynamic depth of field that support a natural focus and merging of a binocular image on an HMD (Camegie and Rhee, 2015). Because the HMD does not have a dynamic depth of field, the users are most likely to develop motion sickness in environments with higher fidelity ratios (Davis et al, 2015). As a result, the VR environment should be designed carefully in order to reduce motion sickness in environments that have higher fidelity, so lots of studies now are integrating VR experiences with locomotive hardware controller methods that provide vestibular and proprioceptive matching stimuli (Aldaba and Moussavi, 2020).

There have been many studies that tried to implement VR locomotive controllers in order to reduce motion sickness. Some of these studies investigated the use of controller that rely on the user being in a static location such as head tilting methods, leaning methods, hand gesturing methods, and walking in place (Lee et al ,2017; Zielasko et al, 2016). Others have focused on utilizing controllers that depends on the user being in a mobile location with a more natural gait method. These controllers included a manual wheelchair joystick (VRNChair) (Byagowi et al, 2014) and Virtusphere treadmill system (Skopp et al, 2014). Most of these studies showed lower motion sickness with the VRNChair showing the most significant results in decreasing motion sickness.

2.1.4 Measurements of Cybersickness

Measuring of the cybersickness that is experienced by the VR user has been measured using objective and subjective measures (Gmaito et al., 2008). Objective measures involve the analysis of physiological activities in the human body. Studies have shown that increase in brady gastric activity, respiration rate (Dennison et al., 2016), heart rate (Nalivaiko et al.,2015), and skin conductance at the forehead (Gavgani et al., 2017) provided a significant indicator of cybersickness in virtual reality. Additionally, there are some behavioural sign that indicate cybersickness such as early termination of a VR experience (Kinsella, 2014) and task competence (Lin et al., 2015).

The other popular approach to measure cybersickness is done through subjective measures which is conducted through questionnaires. Kennedy et al. (1993) presented the Simulator Sickness Questionnaire which measured 16 items including headache, dizziness, and eye strain. Since the nature of cybersickness tend to increase during VR exposure and slowly fade away after VR termination, there are clear challenges when relying purely on questionnaire measurement for predicting cybersickness. Therefore, Weech et al. (2019) predicted that future cybersickness research will most likely implement an integrated approach where physiological measures are combined with multi-item questionnaire when measuring cybersickness.

2.2 Presence in VR

Minsky (1980) introduced the world to the concept of telepresence where he described people interacting through a remote video robot. This introduction has proved to researchers and engineers that it is technically feasible to create an immersive illusion of being somewhere else, and this concept became one the main goals of VR systems(Lombard and Ditton, 1997; Rosenberg,1994;Schubert et al.,2001).Presence is defined as psychological state or subjective perception in which an individual's current experience is generated by and presented through human-made technology and part or all of the individual's perception fail to precisely acknowledge the role of technology in the experience (ISPR, 2000). As a result, it is categorized as a psychological phenomenon that occurs in the human mind and not bound to specific technology. The technology used is just means to arrive at the state of presence in VR. As a matter of fact, if the user was aware of the technology that is used when experiencing virtual reality, the experience of presence will be hindered because presence integrate perceptual illusion of non-meditation where the technology will become invisible and unnoticed by the user (Lombard and Ditton, 1997). As an example, experiencing presence in a virtual environment is similar to viewing a scene through a clear window when a person will not notice the window (the technology itself) when he or she is in a state of presence. In fact, if the user was able to notice the window, the experience would be hindered and the state of presence will be lessened (Thornson et al, 2008). This is not to say that the design of the technology and software used to deliver the Virtual Environment is not important. On the contrary, the technology itself plays a huge role in engaging the user in the environment and driving the user's mind into a state of presence. Therefore, the user's sense of presence plays an important role in achieving the goals and aims of virtual environments (Van Schaik et al., 2004).

2.2.1 Measuring Presence

Since presence is a multidimensional concept that involves complex psychological processes, its measurement has become a central topic of research when designing, engineering and evaluating interactive technologies such as virtual environments (Thornson et al., 2008). There are two general approaches in order to measure the degree of presence that a user is experiencing in virtual reality: subjective and objective measures.

The subjective are conducted through questionnaires measuring tendencies toward presence. It can be done pre-test or post-test (Slater et al., 1994; Witmer and Singer, 1998). The earliest approaches to measuring presence for VEs was conduct by Barfiled and Weghorst (1993). They studied the effect of varying update rate of a computer-generated simulation on the sense of presence in VEs. They developed two questionnaires, one was a 6-item questionnaire to measure presence, and the other is a 7-item questionnaire to measure the fidelity of the interaction. Some of the items were experiment-specific questionnaires and had to be updated and refined in the future studies.

Wittmer and Singer (1998,2005) developed a 32-item questionnaire that was based on the findings of Sheridan (1992) who determined that the underlying factors of presence are sensory information, sensor control, and motor control. They identified three subscales labelled as involvement/control, natural, and interface quality. They also developed the immersive tendency questionnaire (ITQ) to determine the characteristics of the user that affect their sense of presence. This questionnaire is still one the most cited presence questionnaire used in studies (Schwind et al., 2019).

Another subjective approach to measuring presence was introduced by Slater et al. (1998,2000) and Usoh et al.(1999) in lots of studies. The questionnaires measured presence based on three criteria which are, the sense of being in the virtual environment, the extent to which the virtual environment becomes reality, and the extent to which the user remembers the virtual environment as a place. This questionnaire consists of six items, and it is the second most cited questionnaire that is used to measure presence in virtual environments.

The other approach of measuring presence is using objective measures which are conducted through physiological measurements. Slater (2004) argued that presence could not be measured on the basis of post-experience questionnaire and he urged researchers to move away from questionnaires in order to measure presence. This conclusion made researches use physiological measures in order to predict presence because they are more reliable (Schwind et al., 2019). Those measurements are typically conducted during the virtual experience, and the aim here is to observe any physiological and unplanned response to stimuli. The responses include heart rate, skin conductance, blood pressure, muscle tension, respiration rate, ocular response, blinking, pupil diameter and so on (Thornson et al., 2008). While there haven't been enough research to prove whether behavioural measures are reliable, the researchers have found some promising results with physiological measures especially heart rate variability (Meehan et al., 2003).The main advantages of physiological measurements are that they are free of self-report and recollection biases. However, the main disadvantage is the lack of correlations with the degree of presence that is experienced by the user (Prothero et al., 1995).In addition to that, researchers have shown that additional equipment are required to measure physiological responses which can be a great cause to break presence. According to some researchers, presence is a subjective psychological state, and it cannot be captured by objective measures alone (Sheridan, 1992). As a result, measuring presence should be a combination of subjective and objective measurements combined together.

2.2.2 Antecedents of Presence

Personality traits such as level of experience and age have been proven to be important factors that influence presence in virtual reality because presence is a cognitive state, and it makes theoretical sense that personality variables influence the tendency to reach that state (Thornson et al., 2008). These factors are often examined in conjunction with other factors such as absorption, creative imagination, empathy, and cognitive style (Sas and O'Harre, 2003). Stanney and Salvendy (1998) also identified level of experience, the ability to manipulate objects in the virtual world, personality characteristics, and age to be possible significant factors in influencing presence. Similarly, Thornson et al. (2008) proposed factors that are connected to the tendency to experience presence in virtual environments. These factors include age, level of experience, psychomotor ability, cognitive involvement (passive), cognitive involvement (active), spatial orientation, ability to construct mental models, visual learning style, openness to experience, empathy, and introversion.

Age: Bangay and Preston (1998) in their study concluded that subjects between age of 35 and 45 had a tendency to score lower in presence scores when they are compared to the participants of the age group between 10 and 20. Another study done by Schuemie et al (2005) that was conducted on 41 participants did not find any correlations between presence and level of acrophobia, computer experience, gender, and absorption. However, they did discover a significant positive correlation between presence, and the results indicated that as the complexity of the system design rises, the age factor becomes very influential in affecting presence. Therefore, it seems that age group is an important factor in influencing presence in virtual reality environments.

Level of experience: There were different hypotheses suggesting that the level of computer experience that indicates whether a user is a novice or expert has been hypothesized to predict presence, but this factor did not seem to exert direct influence on the users' tendency toward presence, instead it may have affected user's ability to perform in manners which the user understands and organises information , so the logical conclusion is that level of experience affects specifically the ways in which users represent their virtual environment making it affect presence indirect (Thornson et al.,2008). Similarly, Youngblut and Perrin (2002) and Jurnet et al. (2005) studies found no direct link between computer experience and presence and their study showed no relationship or negative correlation between game playing experience and presence, and between VE experience and presence. It appears that previous literature influence of level of experience did not directly influence presence, but it can affect it indirectly, so, in our study, we must also consider whether the computer experience is related to gaming which might indirectly affect presence scores.

Psychomotor ability: Studies have showed that there is a clear link between enhanced spatial abilities and psychomotor task performance (Kyllonen and Chaicken 2003; Keenher et al., 2004). There are possibilities that individual who have active lifestyle and engage in sports or martial arts tend to have higher spatial orientation and abilities.

Cognitive involvement (passive): It is defined as a state where a person if engaged in doing the activity and characterized by feeling energized and active while performing tasks in VE (Thornson et al., 2008). Bornson et al. (1999) concluded that absorption which is defined as the tendency of individuals to be absorbed in everyday events or activities, increases presence in VEs. In addition to that, presence has been found to be linked to Csikszentmihalyi's flow theory (Webster et al., 1993). This theory describes that people experience immersion and presence when they find the activities that they are participating in rewarding where their abilities match the challenges encountered. However, they may experience stress when challenges surpass the user's abilities. Also, the users may experience boredom when their abilities are way above the challenges provided by the experience. Both boredom and stress have been found to be hindering presence rather enhancing it.

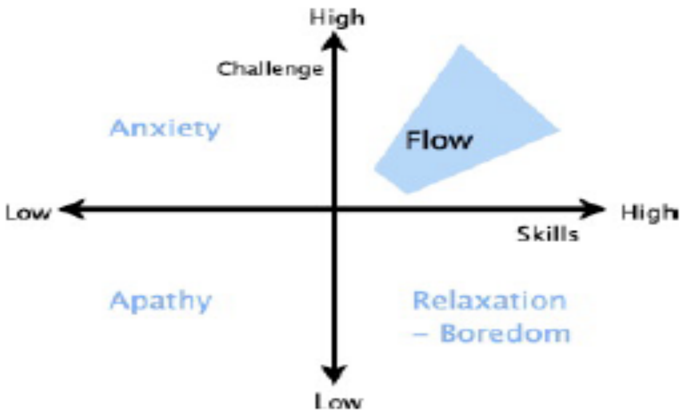


Figure 1 Flow theory with respect to challenge and skill level (Jackson and Csikszentmihalyi, 1999)

Cognitive involvement (Active): It is defined as the tendency to become involved in the tasks that involves judgment and decision making. In such a scenario, the user intentionally tunes out all the distractions internally and externally in order to focus the attention on the experience at hand (Thornson et al., 2008). In a study conducted by Ijsselsteijn (2005), he concluded that interactivity is more important than immersion in virtual experiences. His study showed very interactive levels of display seemed to substantially increase the levels of presence that the user experiences even though these displays were unrealistic. The difference between the active and passive cognitive involvement is that in active cognitive involvement, the user is actively engaged in the task (for example video games), and he chooses to ignore distraction such as personal problems and environment in order to commit all his resources to the experience (Draper et al., 1998).

Spatial Orientation: It is defined as the ability of people to maintain body orientation or posture in relative to the surrounding environment or space where the difference in in such factor lead certain users to perform more efficiently than others in tasks related to information search and information retrieval (Thornson et at., 2008). In addition to that, there are some researches that argued that spatial orientation is more relevant in effecting presence than computer and virtual environments experience. Their argument was based on the fact that spatial orientation predicts the ability of users to construct mental models which has been hypothesised to be one important predictive of presence in virtual reality (Schumie et al., 2005).

Ability to construct mental models: It predicts the ability of a user to construct an accurate mental model representation of himself or herself surrounded by the VE. Studies have shown that when the movement of body parts in VE are represented mentally in the human cognitive process as possible actions, presence is increased (Scubert et al., 2001). Older studies also showed the importance of this ability in predicting presence in virtual environments. For example, Loomis (1992) called this ability "distal attribution", and this ability is compared to having a tool that can become an extension of someone's body when the users utilise it a lot even though this tool is not physically present, and it is not part of the body. Therefore, this ability seems to be a very effective predictor of presence.

Visual Learning Style: Schubert (2001) stated that visual learning style has significant impact on sense of presence. Similarly, Riding (1998) in his study concluded that users with that tend to organize information as visuals are more likely to experience a higher degree of presence that those with verbal or auditory learners. Furthermore, a study done by Slater and Usoh (1993) which used a technique called Neuro Linguistic Programming (NLP) in order to characterise user's physiological representational and perceptual systems showed that the degree of visual dominance was positively correlated with the sense of presence that the users experience, and users that preferred the auditory representational system were experiencing less presence. Based on previous literature, the results appear that the user's learning style have a significant effect on presence scores.

Openness to experience: This factor describes a dimension of personality that distinguishes imaginative and creative people from down-to earth people (Thornson et al., 2008). Previous literature indicates that creative imagination impacts presence in VE where people must implement their imagination in the suspension of disbelief in VE (Sas and O'Hare, 2003). As a result, openness to new experience is related to the user's ability to imagine themselves living in the virtual world.

Introversion: Users who are introverted are usually excited when they are involved with the ideas,reactions,images and memory of their inner world (Thornson et al.,2008). With their ideas pointed towards their inner world, they seem to be excited about ideas that are often better than the something itself, and the ideas are considered to be solid things for them (Myers, 1980). For these reasons, it has been shown by literature that introverts may be able to suppress distracting sensory information than extraverts since they have the tendency towards narrower ranges of attention (Althaus et al., 2004). Therefore, introverts tend to have the ability to suppress conflicting stimuli and utilise their attention on virtual stimuli which increases presence in the virtual world (Schubert et al., 2001).

Empathy: It involves the ability to adopt another entity's psychological point of view and allows them to experience the emotions observed in the experience of others. Studies done by Sas and O'Hare (2003) and Sas et al. (2004) confirmed that users that score higher in feelings tend to experience a higher degree of presence.

2.2.3 Relationship between Presence and Cybersickness

The relationship between presence and cybersickness is still a controversial topic, but the majority of researches suggest that presence and cybersickness are negatively related. In addition to that, the studies that showed an inverse relationship had more compelling and sufficient results to support their conclusions while other studies that showed a positive correlation between cybersickness and presence were not able to confirm the relationships in other section of the study (Kim et al., 2005; Ling et al., 2017). Furthermore, it seems that positive correlation is found between presence and cybersickness due to the fact that "immersiveness" is required in order for a user to experience cybersickness. "Immersiveness" here refers to the degree of sensory submersion that a VR user experience such that external sensory cues are obstructed (Biocca and Delaney, 1995).

Most of the researchers suggest that the there is an inverse relationship between presence and cybersickness because sense of presence suppresses cybersickness because the user shifts his or her attention from factors like sensory conflict which is the main reason for experiencing cybersickness (Cooper et al., 2016). Similarly, the symptoms of cybersickness may suppress the user's attention to the virtual environment and hinder the user from experiencing a sense of presence in VR (Nicholas et al., 2000).

TABLE 1 | Studies assessing the presence-CS link: Negative, positive, and null correlations.

Study	VR Task	Device	*N*	Sign	Statistics	Measures
Witmer et al., 1996	Office navigation	Fakespace Labs BOOM2C	22	–	$r(20) = -0.60$	Presence: PQ CS: SSQ
Wilson et al., 1997 (1)	n.r.	Division dVisor	20	–	n.r.	Presence: PQ CS: SSC
Witmer and Singer, 1998	Multiple tasks	n.r.	n.r.	–	$r = -0.43$ across 4 exp.	Presence: PQ CS: SSQ
Usoh et al., 1999	Room navigation	Virtual Research V8	33	–	n.r.	Presence: SUS CS: SSQ
Nichols et al., 2000	House navigation	Division dVisor	20	–	$r(18) = -0.58$	Presence: SUS CS: SSQ
Stanney, 2000, Unpublished	Maze navigation	n.r.	n.r.	–	$r = -0.34$ (d.f. n.r.)	n.r.
Kim et al., 2005 (1)	Town navigation	Projection screen	61	–	$r(59) = -0.37$	Presence: PQ CS: SSQ
Knight and Arns, 2006	n.r.	Projection screen	387	–	n.r.	Presence: Likert CS: SSQ
Busscher et al., 2011	Video observation	Cybermind Visette Pro	43	–	$r(41) = -0.33$	Presence: IPQ CS: SSQ
Milleville-Pennel and Charron, 2015	Driving simulation	3 LCD screen surround	14	–	n.r.	Presence: Authors' own scale CS: SSQ
Cooper et al., 2016	Car wheel change	Projection screen	8	–	$r(6) = -0.63$	Presence: PQ CS: SSQ
Wilson et al., 1997 (2)	Duck shooting	Virtual I/O i-glasses	24	+	n.r.	Presence: Startle, subjective score CS: SSC
Bangay and Preston, 1998	Rollercoaster	HMD (model not reported)	143	+	n.r.	Presence: Subjective score CS: SSQ
Lin et al., 2002	Driving simulation	Projection screen, CrystalEyes glasses	40	+	$r(38) = 0.44$	Presence: SUS (modified) CS: SSQ
Kim et al., 2005 (2)	Town navigation	3D Visual and Auditory Environment Generator	61	+	$r(59) = 0.35$	Presence: ITQ CS: SSQ
Liu and Uang, 2011	Grocery shopping	n.r.	60	+	$r(58) = 0.67$	Presence: PQ CS: SSQ
Ling et al., 2013	Public speaking	eMagin Z800 3DVisor	88	+	$r(86) = 0.28$ (ITQ/SSQ)	Presence: ITQ CS: SSQ
Mania and Chalmers, 2001	Listening to a seminar	Prototype HP HMD	54	×	$r(16) = -0.4$	Presence: SUS (modified) CS: SSQ
Seay et al., 2002	Driving simulation	Projection screen	156	×	n.r.	Presence: PQ CS: SSQ
Robillard et al., 2003	Asked to approach phobogenic stimuli (spiders)	I-Glass HMD	26	×	n.r.	Presence: PQ, ITQ, subjective score CS: SSQ
Ryan and Griffin, 2016	Sitting in a café	Oculus Rift DK2	28	×	n.r.	n.r.

+ = positive. – = negative. × = null correlation. n.r. = not reported. SSQ = Simulator Sickness Questionnaire, Kennedy et al., 1993; *SSC = Short Symptoms Checklist,* Cobb et al., 1995; *SUS = Slater-Usoh-Steed Questionnaire,* Usoh et al., 2000; *ITQ = Immersive Tendencies Questionnaire,* Witmer and Singer, 1998; *IPQ = Igroup Presence Questionnaire,* Schubert, 2003; *PQ = Presence Questionnaire,* Witmer and Singer, 1998.

Table 1Different studies about the correlation between presence and cybersickness(Weech et al.,2019)

2.3 Avatar-Identification

Avatars are defined as the digital bodies that the users of virtual reality use in order to have an immersive experience in the digital world (Downs et al., 2019). In video games, the main character that the players play as regardless of character development or customisation is regarded as the player's avatar in that video game. In these video games, the avatars are always represented as two- or three-dimensional bodies that the players control every aspect of their interaction in the virtual world. The avatar facilitates all the gameplay experience from gameplay mechanics and immersion to social interactions in the virtual world, and as a result the player's avatar could be regarded as an extension to the player's identity (Little, 1999).

Studies have shown that there is no one statistical test that could confirm the presence or absence of identification between players and respective avatars, but it was confirmed that there is a broader paradigm where identification is a second-order factor that has different number of subconstruct (Downs et al., 2019). The most prominent subconstructs that were used by previous literature and scholars in both traditional media and video games consist of physical similarity, value homophily, status homophily, wishful identification, parasocial identification, perspective-taking, liking and embodiment (Downs et al., 2019).

The literature showed that not all of these subconstruct are necessary for identification to occur between players and their respective avatars (Downs, 2019).Therefore, for our study, we decided to focus on three subconstructs because we believe that these are the most relevant to our project and will provide us with accurate measurement of the degree of identification between our Skyrim players and their respective characters. These three subconstructs are physical similarity, wishful identification, and liking.

2.3.1 Physical Similarity

This subconstruct measures the degree to which an avatar resembles the player in physical appearance. Biocca (1997) in her study showed that an avatar having a graphic visualization of the player in the digital world would enable the players to build a physical and mental model of the self that could be reflected upon. In addition to that, Dowrick (1983) has also shown the importance of self-modelling when it comes to building perceptions of self-efficacy. Other recent studies like Trepte et al. (2009) showed that game players almost always preferred avatars that are similar to the player when it comes to biological sex.

In summary, lots of related work have shown the importance of physical similarity in allowing the players to identify with their avatars, and our study utilises the Skyrim game which allows the participants to customise their character's appearances in the game, and we believe that this is an important subconstruct that will allow our participants to identify with their in-game characters.

2.3.2 Wishful Identification

Wishful identification refers to the desired and shared qualities between a player and his or her avatar, and it is defined as "psychological process through which an individual desires or attempts to become like another person" (Hoffner and Buchanan, 2005, p 327) or in terms of video games the extent to which a player wants to become like his or her respective video game character (Hoffner and Buchanan, 2005).

Wishful identification can influence behaviours in terms of dressing, physical appearance, and attitudes (Boon and Lomore, 2001). Lots of studies have shown that wishful identification played an important part in the lives of children and adults (Hoffner and Buchanan, 2005), and in some cases such identification with characters could be beneficial for people by empowering people with game characters and boosting their confidence and attitudes (Harrell, 2012).

We are going to include the wishful identification subconstruct in measuring our player's identification with their characters because we believe that Skyrim has lots of flexibility in terms of character creation where players will be controlling all the aspects of that character like physical looks, class, skills, decision-making, tasks choice, and weapons to use. Therefore, we think that players will be creating their idol powerful character and they will identify with him or her by wishing they could become as powerful as their character where they will be able to improve every aspect of their avatar as they continually play and explore the game.

2.3.3 Identification as Liking

Another subconstruct that we are going to be using for avatar-identification measurement is liking where previous literature has argued that players could identify with their characters through liking them (Downs et al., 2019). Raney (2004) argued that players tend to like characters whose actions and behaviours are justified by the player, and these players enjoy their games when their characters experience positive outcomes in the game. These positive feelings that the player towards their characters will make players develop strong feelings of empathy towards their avatar which will eventually lead to identification (McDonald and Kim, 2001). In addition to that, previous research believe that the player spends more time playing as their character, they will like, empathise, understand, and becoming emotionally invested with that character (Raney, 2004).

In our study, we are going to include liking as part of measuring avatar-identification of our players with their characters because our players will be spending lots of time controlling their characters, and they will be able to make all the moral decisions for them. In addition to that, our participants will have the freedom to choose any path route for their characters. Therefore, we believe that the players will develop affection and positive feelings with their characters as they spend more time with them and explore the game further.

2.4 Summary

In this section of our study, we presented previous literature that studied presence, cybersickness, and avatar identification. The first section revolved around cybersickness where we discussed the popular theories behind cybersickness, the symptoms of cybersickness, and popular methods that were used to measure cybersickness. In the second part, we discussed presence by first giving definitions of the term presence followed by the different approaches that were used to measure presence in different literature. We also discussed the antecedents of presence which are some certain qualities, characteristics, and traits that people possess which seem to affect the state of presence the virtual reality users experience. Furthermore, we discussed the relation between presence and cybersickness highlighting the different results that previous literature has achieved.

In the final section, we talked about avatar-identification by defining the term and discussing all the subconstructs that we are going to use in our study in order to measure the degree to which our participants can identify with their in-game characters.

Chapter 3

Requirements and Design

In this section we will be discussing the high-level requirements that are needed to implement our experiment. This chapter will be the basis for the implementation section that follows this section. Most of our requirement and design section will be derived from the literature review discussed in the previous chapter in order to improve the state of presence in a VR experience in addition to allowing the participant to identify with their character in the game. We are hoping that our experiment will create an immersive experience that will increase the presence felt in addition to decreasing cybersickness in the long term. We split the requirements section into four categories which are hardware requirements, software requirements, game requirements, and general requirements.

3.1 Hardware Requirements

In order to implement our experiment, we had to identify the required hardware that fulfil our requirements.

3.1.1 Head Mounted Display

Based on the related work that was discussed in the previous section, we know that an HMD is required in order to teleport the player into the world of Skyrim and allow the player to be immersed hoping to sustain the state of presence that the player experience in the game. We are also hoping that the player would associate and identify himself with the in-game character that he chose and customised.

3.1.2 Eye Tracking Features and Capabilities

Physiological measurements are an important part of our research and recording eye data in the form of blink rate and pupil diameter is an important part for our research, so our HMD must also have eye tracking and calibration features.

3.1.3 High Specs Desktop

Since our study requires altering and enhancing Skyrim game with a mods, we will require substantial processing power from the desktop PC in order to handle these requirements. We always have to take into consideration that the mods that we are going to be using are not highly optimised since they are not made by Bathesda professionals (creators of the game), so having a very powerful desktop will decrease the likelihood of encountering lag spikes, stuttering, and performance bugs.

3.1.4Measuring Heart Rate using a Heart Rate Sensor

Another physiological measure that is important to our study is measuring the heart rate of the participants while they are navigating the world of Skyrim. As a result, we will be requiring hardware that has the capability to continuously measure the heart rate of the participants during the experiment which will allow us to easily calculate the average heart rate of participants in different experimental conditions.

3.1.5 Foot Trackers in order to implement walk-in-place functionality

An integral part of our study is implementing the walk-in-place functionality while the participants are playing the game in order to check the effects of implementing such functionality on the state of presence that the participants are experiencing. For this purpose, we require hardware that will track the movement of the feet during the experiment in order to translate the movements of the feet to their respective avatar which would signal different movement sets such as walking, sprinting, sitting, and jumping.

3.2 Software Requirements

3.2.1 Two versions of Skyrim Game

Since Skyrim is the game that we are going to be using for our study, we will require two versions of the game, the standard version where the participants will play the game using the mouse and the keyboard, and the VR version of the game where the game will be played using a HMD.

3.2.2 Software that will record pupil diameter and number of blinks

In requirement 3.1.2, we asserted that the HMD should have eye-tracking and calibration features, and in order to complement these features, we will need a software that would keep track of the pupil diameter and blink rate during the experiment. Our software should be recording these data and save them in a spreadsheet in order to be used for statistical analysis.

3.2.3 Software that would allow easy implementation of different Skyrim mods

As discussed in the earlier sections, we will be altering the Skyrim game with different mods in order to enhance the visuals and the gameplay of the game, so we will be requiring a software that will make the installation of these modes fast and efficient rather than having a complicated process of installing each mod separately.

3.2.4 Software that will be able to read the heart rate and average heart rate during each session

We mentioned in the requirement 3.1.4 that we will require a heart rate sensor that will be attached to the human body during our experimental study, and in order to complement the heart rate sensor device, we will be using a software that can read these measurements and allow us to extract the average heart rate of the participants during different conditions throughout the whole experiment.

3.2.5 List of Skyrim Mods

Skyrim is a game that was released in the year 2011, so it is considered relatively old according to today's standards of games. As a result, we are required to implement different mods in order to improve many elements of the game. Our aim is that these mods should upgrade the game in different categories, and they are as the following:

Visual Improvement:

We need to implement some mods that would improve the visual fidelity of the game including reduced pop-ups, improved textures, and improved rendering of the game assets. The mods should also improve the scenes in the game like mountains, clouds, waterfall, and cities.

Audio Improvement:

Another improvement that we want to improve in the game is the audio quality. We know that the sensory details tend to improve the player's sense of presence as discussed in the related studies section, so improving the 3d audio quality in the Skyrim world is most likely to improve the state of presence that the player feel while playing the game.

Gameplay Improvement:

We consider that gameplay is an important factor that would improve the state of presence in the game and allow the player to identify with his in-game avatar, so we will be implementing different mods to improve different gameplay elements. First, we have to install a mod that would remove the tutorial of the game which is a long boring and time consuming the process that each player will have to go through once they start a new Skyrim game. Second, we need to allow the player to see his in-game character in VR. We want the player to be able to see his character's physical appearance, weapons, and the cosmetics that he decided to equip for his or her character. In addition to that, we will be implementing some mods that would improve some battle mechanics in the game.

3.2.6 A software that would implement walk-in-place locomotion mechanic for the game

An important mechanic that we want to implement in our study is the walk-in place mechanic. We believe that implementing this mechanic would improve the sense of presence and immersion that the player would experience during his gameplay time. As a result, we will be required to implement a software that would be allow the player to move in the game world through walking-in-place in the real world.

3.4 General Requirements

3.4.1 The game must maintain 90 frames per second

One drawback of implementing several mods is the fact that lots of these mods are not perfectly optimised which might lead to drops in the framerate of the game. We are required to keep the framerate at minimum 90 fps in order to avoid motion sickness and maintain the state of presence that the player is experiencing during gameplay.

3.4.2 The HMD must be clean, hygienic, and comfortable for the user

Since the players will be exerting physical activity while walking or running place, the HMD’s screen will most likely fog up and the HMD itself will accumulate sweat from the players. These factors might make the player uncomfortable and minimise their investment and presence in the game, so it is our responsibility to keep the HMD clean and comfortable at all the stages in the experiment.

3.4.3 Participants’ Health must be of highest priority

Although we will be asking our participants to fill health form questionnaires in order to make sure that they are healthy, we should always be aware of the physiological functions of the participants’ bodies. For example, if we notice a very high heart rate (above 150 bps), or if we notice a very abnormal blinking rate, the experiment should be terminated in order to guarantee the safety of our participants.

Chapter 4

Implementation

This section is derived from the requirement and design section where we explain the choices that we made for the implementation process of our experiment, and we will give reasons for making every design choice based on our requirements. For each system choice that we make, we will be presenting some alternative choices that were available and we will explain the reasons for choosing each of our approaches.

4.1 Hardware

The first step in our experimental setup is establishing the hardware that is required to allow our participants to immerse themselves in the Skyrim world, and organised our hardware design as the following:

4.1.1 Computer Desktop

This computer station is an important part of our setup because it is should be able to run the game consistently with a frame rate above 90 fps as mentioned in the requirements section, and we want to minimise the bugs and any sort of frame drops or stuttering during the gameplay. As a result, we will be using a desktop equipped with Intel Core I7-9700K(8 CPUs) running at frequencies of 3.6 GHZ in addition to 64 GB of RAM. The desktop will also be equipped with an NVIDIA RTX 2080 TI hoping to ensure that we always achieve stable gameplay and performance. As mentioned in the requirements section, we are aiming at upgrading the graphical quality and fidelity of the game, so using one of the most powerful graphical processing unit will help us achieve such goal.

4.1.2 Monitor

In order to complete the computer setup, we will be requiring a monitor to display the gameplay of Skyrim during the study. Our study requires participants two versions of Skyrim version games, the original version which is played using a mouse and keyboard, and the VR version which is played on the HMD. For these reasons, we will be required to use a big display with high resolution and fast refresh rate. We had a lot of options available on the market which contains lots of decent gaming monitors, and we ended up using a Samsung Gaming monitor with 4K 32 inches display, high response time, low input lag, and 120 Hz refresh rate. We thought that these monitor specifications fit the requirements of our experiment giving the players great gameplay experience at a very high resolution.

4.1.3 Head Mounted Display

The head mounted display is an important part of our setup as it is the mean that is used for teleporting from the real world and immersing them in the world of Skyrim. After examining the market, we found lots of options available to us that included HTC Vive, Oculus Rift, Playstation VR, and Steam Index.

Upon examining our requirements, we were able to filter lots of available head mounted displays on the market. Our experiment requires us to have an HMD display that is has a high-resolution display and have eye tracking features and capabilities. We decided to use the HTC Vive Pro Eye for our experiment because it was packed with features that fit our experimental needs. First, this HMD have precision eye tracking features that allows us to measure pupil diameter and blink rate of our participants. None of the other alternatives had such precision eye tracking features. Second, the Vive Pro Eye has foveated rendering which allows smart allocation of the GPU workload. This feature improves graphical fidelity in the user's line of sight reducing the rendering load on the GPU and improving performance. Third, this HMD has improved graphics, texts, and textures in the simulations with dual OLED displays displaying a resolution of 2800 x 1600 pixels and 615 PPI. Graphical improvement, and improved performance are main goals in our experiment in order to keep the user immersed and improving the sense of presence that the user experiences. Finally, the design of the Pro Eye is very flexible fitting different head sizes, adjustable optics, and it is very comfortable to wear even to the people who wear glasses. In addition to that, there is a face foam cushion that is attached to the front of the devices which will absorb lots of the sweat that the user experiences during the gameplay which help in preventing the view from being hindered and keeping the participants comfortable during sessions.

Figure 2 HTC Vive Pro Eye

4.1.4 Base Stations

Following the previous section, the implementation of the HTC Vive Pro Eye requires the installation of two infra-red base station for detecting and tracking the position and the orientation of the headset. After covering the HTC Vive standing scale setup, we realised that the headset should be positioned in opposite corners of the standing space with the directions of the base stations facing each other. The manual recommended that we place these base stations at a height above 6.5 ft. However, due to the limitations of implementing the setup in a small room, we couldn't place the base station at these specific heights. In addition to that, we could not mount the base station to the wall as recommended by the manual, so we used normal stands to place the base stations opposite to each other at different corners of the room. Although we did not follow all the instructions in the manual, we did not notice any impact on the gameplay or tracking when we tested the gameplay at different occasions.

Figure 3 HTC Vive Pro Eye Base Stations

4.1.5 Heart Rate Sensor

As mentioned in the requirement 3.1.4, we will be requiring a heart rate sensor that will continuously measure the heart rate of the participants. We wanted to explore several hardware options that will allow us to implement such functionality. First, we tried to use BIOPAC system for measuring heart rate, but such implementation requires that two wires attached from the system to the chest of the participant for continuous tracking. After several testing experiments, we noticed that there were too many wires attached (two wires from the chest to the system and one wire from the HMD to the desktop) and as a result, we were not able to enjoy the gameplay because of the many wires surrounding the participants and that hindered the immersion inthe game especially when we were trying to rotate during the gameplay. After several minutes, the wires would wrap around our legs and as a result we decided to change such implementation.

The other option that we had was using a heart rate sensor with Bluetooth functionality in order to avoid the additional wires and connections. We had the options to use a bracelet Bluetooth sensor that attaches to the wrist of the player or using a chest Bluetooth sensor that is attached to the chest of the player. After we researched the web about these sensors, we noticed some negative reviews regarding the bracelet Bluetooth sensors with users reporting negative review claiming that lots of their measurement were inaccurate. As a result, we decided to use a Bluetooth sensor that attaches to the player's chest with a strap. In the end, we decided to use CooSpo heart rate sensor because it was affordable, and it had many positive reviews on the amazon store. In addition to that, this device was very convenient because it is easily linked to popular mobile applications like Nike+, Elite HRV, and apple health which continuously track the heart rate of the user giving us the average heart rate of the user over the duration of the experiment.

Figure 4 CooSpo Bluetooth Heart Rate Sensor

4.1.6 Feet Movement Trackers

As previously mentioned in the requirement 3.1.5 we will be requiring foot trackers in order to implement the walk-in-place functionality for our experiment. There are many devices in the market that can be used as foot trackers like mobiles, Vive trackers, extra Vive controllers, Nintendo switch joy-cons, Playstation move controllers…etc. As a result, we decided to make our choice based on the customers' reviews and the availability of the devices at our university. For our experiment, we decided to implement Vive trackers for tracking movement because it had positive reviews by the customers and since we are using an HTC Vive HMD, having a Vive trackers will be the best option in term of compatibility between devices and achieving high accuracy of movement tracking. Additionally ,this choice was very easy to implement by linking it to SteamVR by installing the necessary drivers and connecting it to the walk-in place software that was used.

Figure 5 Vive Foot trackers

4.2 Software Design

In this section, we will be discussing the software requirements needed to construct our study that would complement our hardware choices and allow us to utilise the functionality that is needed from our study.

4.2.1 Two versions of the Skyrim Games

In order to install the Skyrim games on our computer desktop we needed to purchase two licences for the game (the original desktop version and the VR version). Upon searching the web, we discovered that we could buy these games from either Steam or Bathesda official store who are the creators of the game. After careful consideration, we decided to buy it from the Steam store because it is the most popular store that offers pc games in addition to having a huge community that is always active and discusses all the issues that we might encounter with the game. Furthermore, the steam offers a free software called SteamVR that is easily compatible with HTC Vive Pro Eye and offers a very friendly user interface that allows us to setup the HMD in addition to allowing us to simply calibrate the user's eye in the HMD.

4.2.2 Tracking heart rate and average heart rate of the participants

As mentioned in the design 4.1.5, the heart rate sensor is compatible with several mobile applications like Nike+, apple health, and Elite HRV applications. In terms of our setup design, none of these applications offer an advantage over the other, so we just decided to use Elite HRV application which is a simple application for tracking heart rate on the mobile that we used in this experiment. This application is so convenient and efficient because it keeps track of the player's heart rate while conducting the experiment in addition to instantly calculating the average heart rate of that player at any point during the experiment. Average heart rate is an important measurement in our design which we will be using our statistical analysis.

4.2.3 Easy installation of different mods

As mentioned in the requirement 3.2.4, we will be requiring a software that allows us to easily implement different Skyrim mods since our setup requires a lot of experimentation in order to achieve the results that we want in our game. After doing lots of research, we decided to implement a very popular software for installing Skyrim mods which is called Mod Organizer 2. First, we created an account in www.nexusmods.com which is a website which contain many Skyrim mods that are available to the player to install in order to alter the game and improve it in different ways. After that, we installed Mod Organizer 2 to our pc where created two different profiles one profile for the normal Skyrim and the other for the VR version of Skyrim. Finally, we linked our nexus account to our Mod Organizer 2 and installed the mods that we wanted to implement in our game. We chose this software because it was convenient, easy to use, and saved us a lot of time in installing the mods that we wanted for our game.

Figure 6 Mod Organizer 2 Software Logo

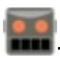
4.2.4 Measuring pupil diameter and blink rate

According to requirement 3.2.3, we will be requiring a software that would measure pupil diameter and blink rate. We decided to create a simple eye data logger in unity that would measure the eye data that we require. This software will just use external libraries and HTC Vive Pro Eye software development kits (SDK). In our unity code, we will be using SRanipal and Tobii XR libraries in order to utilise the Vive Pro Eye eye tracking features and allow us to extract the eye data that we need in our study. This logger will be run alongside the game while participants are playing the game.

Implementing the eye data logger

In order to be able to use the eye tracking features of the HTC Vive Pro Eye we had to first install SR_Runtime software from the Vive website, and after that we ran software on our desktop. The status of the software is represented in the system tray of the computer, and they refer to the following status:

- This status means that the eye tracking is either disabled, or it is not supported by the headset.

- This status means that the eye tracking is idle, and it is not currently working.

 - This status means that the eye tracking features are enabled and in-use.

After making sure that the status of the SR_Runtime is enabled which is resembled by the green eyes of the robot, we opened SteamVR and we calibrated our eyes using the options that are available of the VR dashboard.

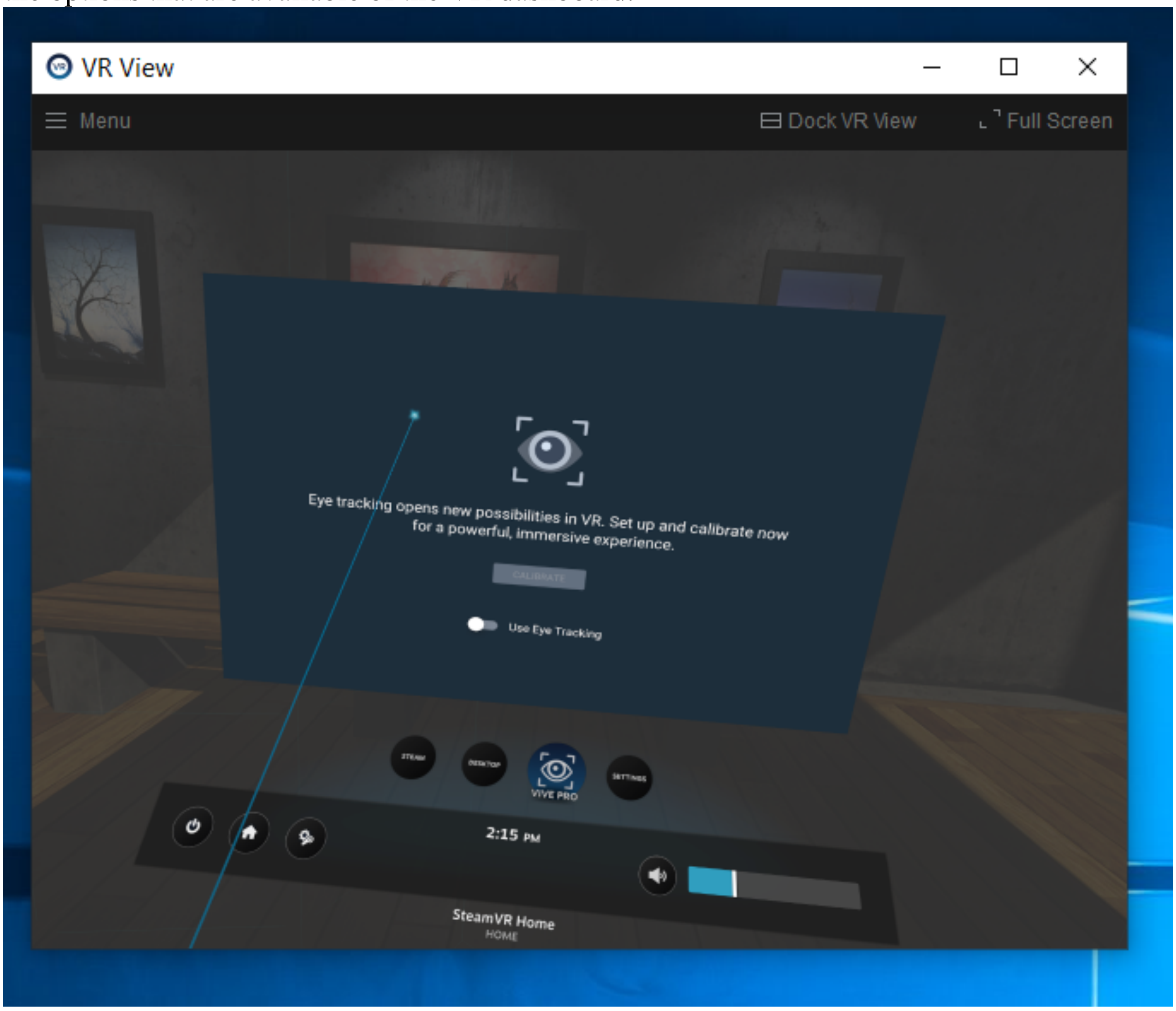


Figure 7 Eye Calibration in SteamVR

After finishing all these steps, we started a new Unity project where we implemented the eye data logger. The process was simple as we created a new script and attached it a game object inside an empty game scene. The code in that script is represented in the following figure:

```
using System.Collections;
using System.Collections.Generic;
using System.IO;
using System.Text;
using Tobii.XR;
using UnityEngine;
using ViveSR.anipal.Eye;
using System.Xml.Linq;

public Eyedatalogger : MonoBehaviour
{
    EyeData vive_eye_data;
    private int blinks_number;
    private StringBuilder string_builder;
    private bool left_eye_blinked;
    private bool right_eye_blinked;

    void Start()
    {
        blinks_number = 0;
        vive_eye_data = new EyeData();
        left_eye_blinked = false;
        right_eye_blinked = false;
        string_builder = new StringBuilder();

        string_builder.AppendLine ("Blinks, Pupil Diameter")
    }

    void FixedUpdate()
    {
        //access the pupil diameter attribute in the EyeData object, and
the blink numbers is incremented whenever the user blinks

            update_Blink_Numbers();

string_builder.AppendLine(string.Format("{0},{1},",(vive_eye_data.verbose_d
ata.left.pupil_diameter_mm +
vive_eye_data.verbose_data.right.pupil_diameter_mm)/2 , blinks_number));


    }
```

Figure 8 Code used in Unity to update number of blinks and pupil diameter measurements

Using the Vive Pro Eye SDK, we created a new game object of type EyeData(), and from this, we were able to access the pupil diameters attributes of both the left and the right eye. These tracking features were appended into a string builder object, and were called every 0.02 seconds by including them in FixedUpdate() method which is a built-in unity method that gets called every 0.02 seconds whenever the program is running.

In addition to that, we created a function called update_Blink_Numbers(). This function is representing the number of blinks that the user experience during a gaming session, and its code is represented in the following figure:

```
private void update_Blink_Numbers()
    {
        //left_eye_blinked and right_eye_blinked are set to false by
default
        // TobiixR.GetEyeTrackingData(TobiiXR_TrackingSpace.World) will get
eye tracking data in local space and the isLeftEyeBlinking bool is true
when the eyes are closed
        if
((TobiiXR.GetEyeTrackingData(TobiiXR_TrackingSpace.World).IsLeftEyeBlinking
&& !left_eye_blinked) ||
(TobiiXR.GetEyeTrackingData(TobiiXR_TrackingSpace.World).IsRightEyeBlinking
&& !right_eye_blinked))
        {
            blinks_number++;
            Debug.Log("You have BLINKED!");
        }
        left_eye_blinked =
TobiiXR.GetEyeTrackingData(TobiiXR_TrackingSpace.World).IsLeftEyeBlinking;
        right_eye_blinked =
TobiiXR.GetEyeTrackingData(TobiiXR_TrackingSpace.World).IsRightEyeBlinking;
    }
```

Figure 9 The method used to track the number of blinks

Using this method, we accessed eye tracking data in local space and access

IsLeftEyeBlinking and IsRightEyeBlinking which returns true if both eyes are closed. Using this functionality, we were able to get the number of blinks in each session by incrementing blinks_number by 1 whenever both eye blink during the VR session.

Calculating Pupil diameter and Blink Rate:

At the end of each session, we were able to calculate the average pupil diameter entries in the string builder and calculating the average of all of these entries and keeping the numbers rounded to two decimal values (In our calculation, we excluded all the readings that had 0 pupil diameter because that meant that the eyes were blinking at that moment, and the actual length could not be tracked). As for calculating blink rate we extracted the final blink number in the string builder entries which represented the total number of blinks that the user experienced during the game session. After that we calculated the blink rate per minute by dividing the total number of blinks by the number of minutes that were spent during a specific session (In our calculation, we kept the blink rated rounded to full integer numbers with no decimals).

4.2.5 walk-in-place functionality:

Following the requirement 3.2.7, our experiment requires a software a walk-in-place functionality and since we are using Skyrim which is a prebuilt game and not a game that we developed from the ground up, we decided to also use a prebuilt software that is compatible with the game which equips the game with the walk-in-place functionality. The software that we decided to use is called Natural Locomotion. The software is available on the steam store, and it is overwhelmingly positively reviewed by the players who play VR games. The software is compatible with many VR games including Skyrim, and it offers lots of advantages to our study. First, it allows us to easily implement the walk-in-place functionality without any complications or obstacles which is very efficient and crucial to the success of our study. Second, it has many advanced settings in the movement mechanics which gives us lots of flexibility in implementing the settings that are suitable for our setup. Finally, this software offers two movement modes in VR games. The first one allows the user to move in the game by swinging his or her arm holding the joystick, slow swinging will allow the character to walk while faster ones would make the character run. The other mode utilises the addition of feet trackers to the setup and allows the user to move in the game by physically walking or running in place. We are going to utilise both of these modes in our study and testing the effects of implementing different movement mechanics in the game. For all these reasons mentioned, we decided to use the Natural Locomotion software.

Figure 10 Natural Locomotion Software Logo

Natural Locomotion Settings:

As mentioned before, Natural Locomotion software has a lot of advanced settings that we can tweak in order to get the functionality that is need in our study. First, we created a new profile setting for Skyrim VR, and this profile will be used for our experiment. We extensively tested these settings in order to achieve the best results for our setup and the most natural and balanced gameplay. We ended up with choosing the following setup for our game:

- Enabled jump in place functionality
- Speed multiplier was set at 100%
- Sprint Threshold was set at 100%
- Max speed was set at 2.5m/s
- Orientation was set in the HTC Vive Joystick direction

We chose to enable the jump in place functionality because we wanted to give the player the flexibility to jump during the gameplay in case, he chooses to do that, or the game forces him to jump at certain points in the story mode. Speed multiplier refers to how much speed is scaled before having it emulated into the game input. We tried to increase this multiplier beyond 100% but the gameplay didn't feel natural, and as a result, we set it to 100%. Sprint threshold refers to how fast the player has to move in place before the sprinting functionality triggers. During our testing phase, we tweaked these values to above 100%, but we noticed that we had to move faster in place for our character to sprint in the game, and such effect hindered the immersion and the state of presence within the gameplay, therefore, we kept it at 100%. With respect to max speed, it refers to the maximum speed that the character can walk within the gameplay. During the testing, we tested increasing it to above 2.5 m/s, but this caused to breaking the gameplay feel unnatural and the game became too easy, and it felt like we were able to navigate the environment at very high speed. In addition to that, increasing the max speed caused some problems with rendering the assets, and it led to some unexpected bugs which we are trying to avoid. As for the orientation, it refers to the direction that the character in the game would move towards and it can be set to be either relative to the Vive controller or to the head direction. At the beginning, we tried setting the orientation relative to the direction of the head, but as we played more, we found it hard to play because we could not strafe left and right while looking in a different direction especially during combat, so we had to adjust it to making the orientation to be based on the joystick direction. Having said that, we still have to acknowledge that in some situations during the gameplay, having the character move in a direction different from the direction that your body is facing felt like it was breaking the immersion in the game, but we still kept this setting to keep the game playable and fun when undertaking hard quests that required some mechanical precision in the movement of the player's character.

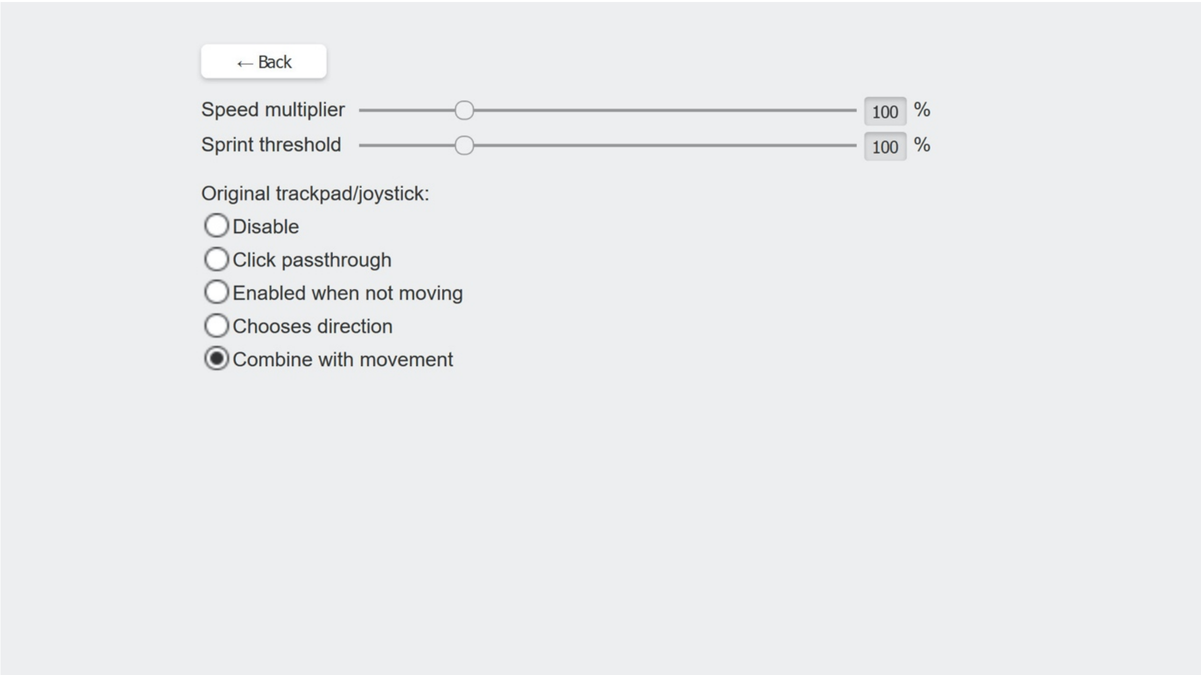


Figure 11 Settings screen for Natural Locomotion Software

4.3 Game Mods:

As mentioned in the requirements 3.2.6, our study requires that we should improve the Skyrim game in terms of graphics, audio, and gameplay using several mods that are available on www.nexusmods.com . Our main challenge was to sustain a balance between improving the game with mods and keeping an optimum game performance that does not suffer from lags, stutters, bugs, crashes, and frame drops. This process required a lot of trial and error where we installed different mods and tested the gameplay to check the performance of the game, and if the performance suffered from the implementation of mods, we were forced to delete the mod. Such process was made simple by utilising Mod Organizer 2 software. We noticed that most of the mods that were causing performance drops were some unoptimized graphics mods and 4k mods. As a result, these mods were not included in the design of our study. After a long process of trying mods, we ended up with a list of mods that were used in this study. These mods improve gameplay, graphics, and audio. We will be discussing the effects of each mod on the game. The list of mods that were implemented in our study are represented in the following table.

Mods	Category
True 3D Sounds For Headphones	Audio
Audio Overhaul for Skyrim	Audio
Realistic Water two	Visual
Skyrim 2020 PARALLAX	Visual
VRIK	Gameplay
Alternate Start-Live Another Life-SSE	Gameplay
Unofficial Skyrim Special Edition Patch	Visual
Scenery ENB VR for Skyrim VR	Visual
Real Clouds	Visual
Simple Realistic Archery	Gameplay
True Storms Special Edition	Visual
Enhanced Lights and FX	Visual

Table 2 List of mods used for Skyrim

True 3d Sounds For Headphones:

This mod enables 3D sound positioning in the game. The player will be able hear from which direction is the sound coming from. This enhancement is established by using head-related transfer function (HRTF) in order to stimulate binaural hearing with the usage of normal stereo headphone. We believe that this mod will enhance immersion and presence in the game by simulating the ways real physical sounds are perceived by the brain.

Audio Overhaul for Skyrim:

This mod aims at making Skyrim's sounds more immersive by changing the sounds of creatures, propagations, movement, weapons, and magic. The change in these sounds and tones will use more real-life audio behaviour rather than using gamey sound effects. We believe that this effect will make the world more immersive for the player that is roaming the world.

Realistic Water Two:

This mod enhances the textures and the geometry of the water where the water flow system bend, turns around, and change speed depending on the environment that the player is experiencing during the game. During our testing phase, we found that the quality of the water assets that this mod provides is very impressive and we considered it to be a huge improvement over the waters that were present in the original version. The flow of the water felt so natural, and it was impressive to look at.

Figure 12The effect that Realistic Water Two has on the game
"www.nexusmods.com"

SKYRIM 2020 PARALLAX:

This mod contains a package of high-resolution textures which improves the visuals of the general environment that are surrounding the player. While testing the game, we noticed a huge improvement in the textures of the ground while we were experiencing the game especially the ground textures and we believe that this mod was a huge improvement in the visuals of the game.

Figure 13The effect that Skyrim 2020 PARALLAX have on the game "www.nexusmods.com"

VRIK:

This mod is exclusively used for the Skyrim VR and it helps with improving the player's immersion during the gameplay. The original Skyrim VR allows player to only see the hands of the player while interacting with the simulated world which is not very immersive because the player will not be able to see his character's arms and body. Fortunately, this mod fixes this problem by displaying the character's body and animate it to match the player's physical movement. In addition to that, players are allowed to keep and draw weapons from fourteen holsters that are present on his character's avatar.

Figure 14 The character becomes visible using VRIK mod

Alternate Life Live Another Life SSE:

This mod does not impact or enhance the game in any aspect, and it was only implemented for experimentation purposes. The original Skyrim starts with a long tutorial where the player would just listen to a man on a carriage, and this scene is long and does not fit our experimental needs. This mod eliminates this issue by removing this tutorial scene and places the player straight into the Skyrim world to interact with the game from the start. This process is important for our study because the condition of our experiment have time constraints and we want the player to utilise the experimentation time interacting with the game and immersing himself or herself in the world.

Unofficial Skyrim Special Edition Patch:

One important part of our experimental setup is decreasing the number of bugs present in the game in order to sustain the state of presence in the player and allow the player to connect with his character, and this mod will help us achieve this goal. The mod contains a patch of bug fixes that were not officially resolved by the developers of the game. The bugs fixes include fixing different elements of gameplay, quest, NPC, object, item, text and placement fixes.

Scenery ENB VR for Skyrim VR:

This mod is exclusively used for the Skyrim VR version of the game, and it provides lots of visual improvements to the game including vivid weathers, and lightning overhaul which supports a realistic visual experience. The list of features that this mod provide are as the following:
-color correction
-sharpening textures
-improved rain
-improved glowing lights
-better sky lightning
- new weather conditions created
-natural bloom
-implementing wet-effect during rainy weathers

Figure 15 The effect that Scenery ENB has on the game “www.nexusmods.com”

Real Clouds:

This mod adds volumes to the cloud and makes the clouds look like realistic 3d clouds. These clouds change in coverage and altitude with different weather conditions. For example, the rain clouds that you view from long distance can become fog-like from close distance perspective. During our testing phase, we were very impressed with the sights of the clouds where these simulated effects were so immersive and felt like real world clouds. Therefore, we believe that this mod will improve the sense of presence and immersion of the player.

Figure 16 The effect that Real Clouds have on the game “www.nexusmods.com”

Simple Realistic Archery:

This mod is exclusive to the Skyrim VR version of the game, and it adds to the level of immersion in the game. In essence, this mods adds more mechanical requirements to using the bows in the game where the player has to physically move their hand over their shoulder and pressing the trigger button (which depends on the key bindings used by the player) in order to draw an arrow from the character’s quiver. During our testing, this feature was very immersive forcing us to physically draw an arrow after shooting one, and we believe that it will add to the level of immersion to the players who choose to utilise the bow as their main weapon during combat in the gameplay.

True Storms Special Edition:

This mod improves the game with further visual enhancements in the storm and weather system of the game. The package contains several unique weathers, intense sound effects, interior sound effects, particle effects, new rain particles, new fog textures, and new dust textures. The aim of this mod is further enhancement in the visual fidelity of the game making it more realistic and immersive.

Figure 17 The effect that Trues storms has on the game “www.nexusmods.com”

Enhanced Lights and FX:

As the name of the mode infers, this mod will enhance the lightning system and FX in the game in order to create a realistic mood that improves the Skyrim lightning system. For example, this mod would make lots of interiors and dungeons in the game darker similar to the lightning effects that you would encounter in real life dark rooms with minimal lightning. We believe that this mod would make the interior scenes in the game resemble real life improving presence and immersion.

Figure 18 The effect that Enhanced Lights and FX have on the game
"www.nexusmods.com"

Chapter 5

Evaluation

In this section we will discuss the experimental procedure and execution in addition to interpreting the results of our studies. Our overall aim is to study the presence, cybersickness, and avatar-identification scores of the participants across different conditions and finding relations between these scores. We will also be tracking different physiological measures that were mentioned in the previous chapters and checking the effects and correlations of implementing different conditions. Our experiment is separated into two different studies where they will be conducted at different times. We will start with the first study, and then participants will be asked to participant in the second study.

5.1 First Study:

5.1.1 Experimental Design:

After we have implemented the whole setup that was discussed in the implementation section, we had to design the experiment that we required to achieve our aims and goals. After careful consideration, we divided our first study into four conditions where each condition represents a Skyrim game section that lasts for fifteen minutes.

5.1.1.1 Independent Variables:

For our study, the conditions that were implemented represents the ways that the player play and interact with the game. We designed four ways that the player can play the improved version of Skyrim. These conditions represent our independent variables, and these conditions are represented as the following:

1- Playing the original version of Skyrim called Skyrim:Special Edition (Screen): In this condition, the participants will play the mod-improved

Skyrim game using mouse and keyboard, and all the gameplay will be displayed on the 4k monitor that we have implemented in our experiment.

2- Playing the VR version Skyrim of the game while sitting down on a chair (**SitVR**): In this condition, we change the game to SkyrimVR where the player will play the modded VR version of Skyrim while sitting on the chair. The players will interact and play the game using HTC Vive Controller, and the gameplay will be displayed on the HTC Vive Pro Eye HMD.

3- Playing the VR version of Skyrim game while standing up in the play area of the room (**StandVR**): In this condition, the participants will continue using the modded Skyrim VR, but in this condition they will be standing up in the play area, and in addition to that, the players will be using the Natural Locomotion software mechanics where they have to swing in their arms in order to move in the virtual environment. All the rest of the interactions in the game world like dialogue, equipping items, and combat will be done through HTC Vive controller, and the gameplay will be displayed on the HMD.

4- Playing the VR version of Skyrim game while walking-in-place in the play area of the room (**WalkVR**): In this condition, the participants will continue of using the modded Skyrim VR, and they will be still standing up in the play area. However, in this condition we added ViveTrackers to the setup where these trackers are attached to the ankles of the participants. In this condition, we utilised the other features of Natural Locomotion software where the participants have to walk or run in place in order to move in the virtual environment. The rest of the setup remains the same as previous condition where HTC Vive controller is used for interacting with the world, and the gameplay will be displayed on the HMD.

5.1.1.2 Covariables:

When setting up our experiment, we identified two covariables which might affect the presence, cybersickness, and avatar-identification scores in our experiment. These two covariables are:

1- **Learning Style**: As mentioned in the related study section, the learning style of people tend to have an effect on the sense of presence that the users experience during VR, so we will be categorizing our participants into visual, auditory, and kinaesthetic learners based on pre-experimental questionnaire which will be identified later in a later section.

2- **Immersive Tendency**: According to our related study section, there are lots of characteristics and personal traits that seem to affect sense of presence that the user experience during a VR session. As a result, we are going to use a pre-experimental immersive tendency questionnaire in order to check if the results impact the sense of presence that users experience. This questionnaire will be discussed in more details in the questionnaires section.

5.1.1.3 Dependent Variables:

For our experiment, we defined the variables that we want to measure in our study. Our choice of dependent variables is based on our related studies, and they are derived directly from our research questions. Our dependent variables are as the following:

1- **Average Heart Rate**: This is an important objective measurement that we wanted to use in our experiment in order to test the relation between heart rate and presence scores and check for correlations and relations between the two of them. The average heart rate is extracted post-condition using the elite HRV mobile application.

2- **Average pupil diameter**: Another important objective measurement that we want to use in our analysis is the average pupil diameter post experimental conditions. This measurement will be extracted at the end of every condition except (screen) condition where the HMD will not be used by the participants. This measurement will also be checked for correlation between pupil diameter and presence scores.

3- **Presence Scores**: This is the most important repeated subjective measurement in our experiment where this score is going to represent the state of presence that the participant is having in each of our experimental conditions. This score is acquired by calculating the overall score of presence questionnaire which is a post-conditional questionnaire that we are going to implement in our experimental design.

4- **Cybersickness Scores**: Another important repeated subjective measurement in our experiment is the cybersickness score which represents an overall motion sickness feeling that the user experiences post experimental conditions except (screen) condition where the HMD will not be utilised. The score is calculated using the SSQ cybersickness questionnaire. We will be checking the changes in cybersickness scores post different conditions and establishing a relationship between cybersickness scores and presence scores.

5- **Avatar-Identification Scores**: In addition to the other repeated subjective measurements we will also be using avatar-identification scores for our statistical analysis. The scores will be calculated through a self-identification questionnaire post-experimental condition except for (screen) for the same reasons that we mentioned before. These scores will help us identify how participants are getting attached to their in-game character, and the rate of change of such bond with different experimental conditions.

6- **Blink rate**: We will also be extracting the average blink rate as another objective measurement using our eye data logger. This measurement will be extracted at the end of each condition except (Screen) condition where the participants will not be using an HMD for that condition. We will also be checking for correlation between this measurement and presence scores that the users achieve at the end of each experimental condition.

7- **Qualitative Comments**: These comments will help us analyse the overall game experience that the participants experienced during different conditions. We will be asking our participants for feedback about the gaming experience that they had with different experimental conditions. These comments could provide us with further details about their immersive experience that could not be captured by the questionnaire results.

5.1.1.4 Questionnaires:

In this section, we will be discussing the questionnaires that were used in our experiment with further depth and details regarding each questionnaire. This section is divided into three parts Screening questionnaires, Pre-Experiment Questionnaires, and Post-Condition Questionnaires.

Screening Questionnaire:

- **University of Bath Health Screening questionnaire**: This questionnaire consists of several yes/no questions to the participants, and it requires doctor consent if the participants answers to any of these questions was deemed to pose a risk on the participant’s health during the experiment.

- **Participant Consent Form**: This is a checklist that the participants are going to fill in order to give full consent about participating in our experimental study.

Pre-Experiment Questionnaires:

The questionnaires in this section are provided to our participants before the experimentation starts. The goal of these questionnaires is obtaining general information about the participants state and gather some information about our participants like their self-perception, learning style, and immersive tendencies.

- **Self-perception Questionnaire**: This questionnaire is derived from the general self-efficacy scale by Chen et al. (2001) and Self-Efficacy for Exercise (Resnick and Jenkins, 2000). The questionnaire is made up of 10 question items that are measured on a scale from 1 to 5, and it is used for comparison purposes where participants will be asked to fill the same questionnaire post study two. The total overall score is the sum of all the items score, and it indicates the tendency of the participants to believe in themselves and face challenges in addition to their tendency to exercise and engage in physical activities.

- **Immersive Tendency Questionnaire**: This questionnaire measures the antecedents of presence, and it is derived from ITQ questionnaire by Witmer et al. (2005) and the questionnaire presented by Thornson et al. (2008) research. The questionnaire is made up of 24 question items that are measured on a scale of 1 to 7 where 1 corresponds to never and 7 corresponds to very often. The questions measure antecedents of presence that are mentioned in the related work section, and they are divided into different subscales. These subscales are empathy, constructing mental models, absorption, introversion, spatial orientation, active involvement, and level of gaming experience. The overall score is the total sum of all the items included in the questionnaire.

- **VAK Learning Style Questionnaire**: This questionnaire is used to categorise our participants into three different learning styles visual, auditory, and kinesthetic/ physical learners. The questionnaire is made up of 10 questions, and the participants are represented with three possible choices to pick from. Each answer is linked to a certain learning style, and the overall learning style of each participant is chosen based on the majority of the answers that the participant provides. For example, if the majority of the participant's answers resemble visual learning, he or she will be categorised as visual learner.

Post-Experimental Questionnaires:

These questionnaires are represented to the participants after finishing each condition in our experiment.

- **PQ Questionnaire**: This questionnaire was presented by Witmer et al. (2005), and it consists of 32 question items that are measured on a scale from 1 to 7. These questions represent different subscales that directly affect the sense of presence that the user is experiencing. These subscales are involvement/control, natural, auditory, haptic, resolution, interface quality. Using this questionnaire, we will be able to calculate the presence score of each participant after each condition. The presence score is represented as the total sum of all the question items that are present in this questionnaire.

- **SSQ Questionnaire**: This questionnaire was presented by Kennedy et al. (1993), and it aims at calculating the cybersickness score that a participant is experiencing during certain condition. The participants are presented with 16 cybersickness symptoms, and they have to check the symptoms that they experienced during every experimental condition. These symptoms are weighed across three types of motion sickness which are nausea, oculomotor, and disorientation. The total cybersickness score is calculated by adding the total weights of nausea, oculomotor, and disorientation followed by multiplying the number by 3.74 for an overall cybersickness score. This questionnaire is used post every experimental condition used except the first (screen) condition where the gameplay is displayed on the monitor without the usage of HMD.

- **Avatar Identification Questionnaire**: We will be using this questionnaire to calculate the avatar identification scores for each participant post the experimental conditions except for the (screen) condition because we believed that the participant will not identify with his character after 15 minutes of gameplay. On the other hand, they will be able to identify with the characters that they create in the VR game because the participants will spend couple of experimental conditions with the same character that they created. This questionnaire was derived from Down et al.'s (2019) polythetic model of avatar identification where we extracted three subscales from that questionnaire, and these subscales are used to measure the degree to which our participant identify and bond with their in-game characters. This questionnaire is made up of 12 question items that are measured on a scale from 1 to 7 representing different subscales. These subscales are physical similarity, wishful identification, and Liking. The overall avatar-identification score is represented as the average of all the 12 items that are present in the questionnaire.

5.1.2 Experimental Procedure:

In this section, we will be exploring all the steps that were performed from the start of the study up until its completion. The list of steps that we conducted for each of the participants is carried out as the following:

1- The participants were asked to be present at the room in which we had the design of the experiment implemented.

2- The participants were given an overall description of the experiment, and we gave them the instructions that should be followed for a successful implementation of our experiment.

3- Using the desktop computer that we have; participants were asked to fill the screening health questionnaire and the participant consent form.

4- If the screening questionnaire checks out, we were ready to continue with the experimentation where participants were given the chance to ask about any unclear information in the instructions sheet.

5- The participant was asked to fill all the pre-experimental questionnaires.

6- The participant was then asked to attach the Bluetooth heart rate sensor to his chest using the strap provided.

7- After that we ran the modded Skyrim desktop version, and we gave the participants the freedom to set the key binding that they were most comfortable to use in-game, and we informed that them that they were allowed to change these binding anytime during the gameplay. If such a thing occurs, we had to stop the session timer until the participant finishes the editing process and returns back to the gameplay.

8- Following the flow theory, we decided to set the difficulty of the game to adept making the game not so easy that the player lose interest in the game, and at the same time we would not want it to be very difficult and requiring skills that the participant does not possess thus breaking the immersion in the game.

9- The participant was then allowed to create the character that he would like to play as modifying all the physical features that he wants to change. At this point, we informed the participants that they don't have to heavily customise their character because this character was only going to be used for a 15-minute session gameplay, and after that we will be switching to another version of the game.

10- After everything is set, we start the 15-minute session timer as soon as the gameplay starts. At this point, the participants are given the freedom to play the game freely and engage in any activity that they want in the virtual world.

11- After finishing the 15-minutes session, the participant was asked to fill all the post-condition questionnaires while we recorded the average heart rate during the session using the Elite HRV mobile application.

12- At this point, we were ready to start with the VR conditions where the participant was instructed to wear the HTC Vive Pro Eye Headset and adjust the straps in order to make the headset comfortable to wear and secure.

13- After that, the participant was asked to move to the middle of the room and sit on a chair in the middle of the play space. We briefly reminded the participant will now be using HTC Vive controllers to navigate and interact with the virtual world of Skyrim.

14- We performed eye calibration for the participant using the SteamVR dashboard in order to get accurate eye data in the 15-minute gameplay session.

15- After that we ran the modded SkyrimVR, and we allowed the user to tweak the controller settings according to his preference and liking.

16- When everything was set, the participant was started creating the character that he was going to be using is his game. At this point, we advised the participant to heavily customise the character because that was the character that he will be using for the rest of our experiment.

17- After everything is set and we started the gameplay session, we ran the eye logger to get all the eye data during the condition, and we started the 15-minute timer for the condition.

18- At the end of the session, we saved the game and asked the participant to fill all the post-condition questionnaires while we recorded the average heart rate using the Elite HRV application, and we also recorded the average pupil diameter and blink rate for that condition.

19- After that we were ready to start the third condition gaming session. We briefly reminded the participant about this condition, and we repeated the same steps that were implemented in the previous condition however in this condition we added Natural locomotion software to the game where the players had to swing their arms to walk and run in the Skyrim world. We removed the chair from the middle of the play space allowing the players to stand up there and play the game.

20- After making sure that the participant understood all the new movement mechanics implemented which includes walking, running, moving backwards, and jumping. We loaded the previously saved game and started the 15 minutes gaming session.

21- At the end of the session, the progress was saved, and the participant once again was asked to fill the post-condition questionnaire while we recorder average heart rate, pupil diameter, and blink rate.

22- For the final condition, we attached Vive trackers to the ankles of our participant. After that, we linked these trackers into our desktop, and then we implemented the walk-in place functionality using the Natural Locomotion software. The rest of the setup remained the same as the previous condition that we implemented.

23- After that, the participant was reminded about the new movement system that was implemented where he had to walk or run in place in order to move in the virtual world. We also reminded the participant that he can strafe left and right by pointing the Vive Controller in one direction and looking in any other direction.

24- Once everything was clear, we loaded the previous save and started playing carrying on with his gameplay setting the session timer for 15 minutes.

25- Once the session is done, the progress was saved, and the participant was asked to fill post-condition questionnaire while we recorded the same objective measurements that were recorded in the previous condition.

26- At the end of the experiment, we interviewed the participant and asked him for valuable feedback asking him about the overall experience, likes, dislikes, level of immersion, and any additional information that would be valuable for our analysis.

In addition to all these steps, we decided to implement **stopping criteria** in case something unexpected happened during the experimentation. Our study would be stopped if one of the mentioned criteria occurs during the experimentation process:

1- **Heart rate going above (150 bpm)**: Our experiment is not purely an exercise experiment where participants keeps running during the whole gamin session. Our study allows participants to walk, run, engage in dialogues, and read different item descriptions from the game, so we are not expecting our participants to keep on moving in place during the gameplay session. As a result, if we notice a very high heart rate, we would terminate the gameplay immediately because the safety of our participants is our priority.

2- **Unusual shortness of breath**: if we notice that our participants are experiencing unusual shortage of breath, our experiment would be terminated.

3- **Symptoms of poor blood flow was detected**: If a participant showed signs of low blood flow, such as pale skin, cold or clammy skin, or cyanosis (bluish discoloration), the experiment would be terminated for the safety of the participants.

4- **The participant requests to stop**: the experimental study would be terminated immediately terminated if the participant became uncomfortable and requested that he wanted to stop the experimentation.

5- **Hardware and Software crashes**: In case a hardware or software crash occurs, or the gameplay experience did not fit the standards that we wanted with users experiencing bugs, stuttering, frame rate drops, we will stop the gaming session and restart it with implementing the same conditions that were used when the crash or performance issue occurred.

5.1.3 Hypotheses

In our study we will analyse the following hypotheses:

(H1) The presence score of the participants will increase as we progress through the different conditions of the study.

(H2) The cybersickness score will decrease as we progress through the different conditions of the study.

(H3) The cybersickness score will negatively correlate with the presence scores.

(H4) The learning style will predict presence scores of the participants.

(H5) Pupil diameter will positively correlate with presence scores.

(H6) The blink rate will negatively correlate with presence scores.

(H7) Heart rate will positively correlate with presence scores.

(H8) Avatar identification scores will increase as we progress through the conditions of the study.

(H9) Avatar identification scores will positively correlate with presence scores.

(H10) Immersive tendency score will predict presence scores.

5.1.4 Results

In this section, we will be discussing the statistical analysis that we used in order to accept or reject our tested hypotheses. Due to the pandemic that is invading the world these days and due to the limited number of players that were ready to participate in our experiment, we only managed to evaluate N = 5 participants where all the participants were males and the average age of the sample = 25.8.

5.1.4.1 Presence Scores

In order to assess (H1), and test how the presence scores of the participants change as a function of different experimental conditions, we used repeated measures ANOVA for checking how the presence scores change in our different conditions (Screen, SitVR, StandVR, and WalkVR).

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Condition	577.350	3	192.450	72.395	< .001	0.948
Residuals	31.900	12	2.658			

Note. Type III Sum of Squares

Table 3 Repeated Measures ANOVA of Presence Scores across different experimental conditions

The results of our test suggest a very significant difference in presence scores between different experimental conditions ($F(3,12) = 72.395$, $p<0.001$, $\boxed{\eta^2} = 0.948$). A closer inspection about average presence scores reveal the results represented in the following figures.

Descriptives

Condition	Mean	SD	N
Screen	106.200	7.791	5
SitVR	114.600	7.635	5
StandVR	115.800	6.419	5
WalkVR	121.200	6.458	5

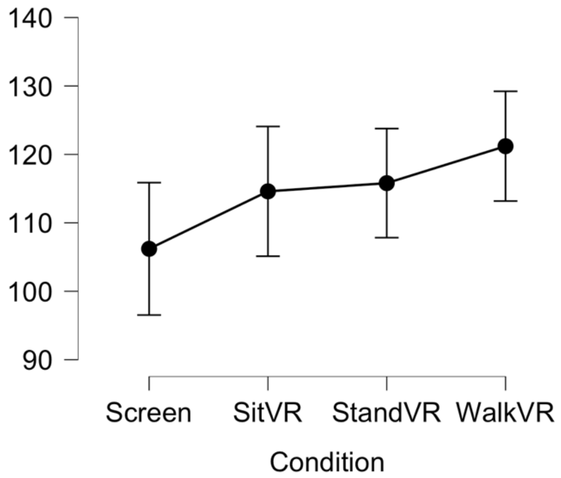


Figure 19 The change in Presence score across different experimental conditions

As shown in the figure, the results indicate an increase in the average scores of presence as we progress through the conditions of the experiment. In order to further investigate the effect of change of presence score between conditions, we decided to use Post Hoc Tests with Holm's correction, and the results are represented in the following table.

Post Hoc Comparisons - Condition

		Mean Difference	95% CI for Mean Difference		SE	t	Cohen's d	p_{holm}
			Lower	Upper				
Screen	SitVR	-8.400	-10.874	-5.926	0.510	-16.474	-7.367	< .001 ***
	StandVR	-9.600	-14.825	-4.375	1.077	-8.913	-3.986	0.004 **
	WalkVR	-15.000	-21.860	-8.140	1.414	-10.607	-4.743	0.002 **
SitVR	StandVR	-1.200	-4.765	2.365	0.735	-1.633	-0.730	0.178
	WalkVR	-6.600	-12.461	-0.739	1.208	-5.462	-2.443	0.016 *
StandVR	WalkVR	-5.400	-10.153	-0.647	0.980	-5.511	-2.465	0.016 *

Note. P-value and confidence intervals adjusted for comparing a family of 6 estimates (confidence intervals corrected using the bonferroni method).

Note. Cohen's d does not correct for multiple comparisons.

* $p < .05$, ** $p < .01$, *** $p < .001$

Table 4 Post Hoc comparison of presence scores across different experimental conditions

The change in the in the presence score from Screen condition to SitVR ($t = -16.474$, Cohen's $d = -7.367$, $p< 0.001$) was very significant which indicate the boost in the state of presence that the user experienced as they transitioned from the normal Skyrim version to the VR version.On the other hand, the change of presence from SitVR to Stand VR (t=-1.633, Cohen's d = -0.730, p = 0.178) was not significant suggesting that the change between these two conditions did not boost the player's sense of presence. In contrast, the change between StandVR and WalkVR (t=-5.511, Cohen's d = -2.465, p= 0.016) showed a significant change in the presence scores of the participants. These statistical results were backed up by the participants' comments at the end of the experiment where they described the change from the normal Skyrim to the VR version a totally different experience when it comes to immersion and presence. On the other hand, they described that changing from sitting VR position to a standing position where the movement was done through swinging their arms towards a certain direction as a small change that did not have a big impact on their gameplay, but the addition of running and walking in place mechanic added levels of immersion to the game. After all the analyses that we have done, we have accepted our first hypothesis.

5.1.4.2 Cybersickness Scores

For assessing (H2), we used the same statistical analysis in order to interpret how the cybersickness scores change as a function of the changes in the experimental conditions. Therefore, we used repeated measures ANOVA to detect the changes in cybersickness scores across our experimental conditions (SitVR, StandVR, WalkVR), and the results are represented in the table below:

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p
Conditions	236.857	2	118.428	63.500	< .001
Residuals	14.920	8	1.865		

Note. Type III Sum of Squares

Table 5 Repeated measure ANOVA across different experimental conditions

The results of our test suggests a very significant difference in the cybersickness scores across the different experimental conditions (F(2,8) = 63.500, p<0.001). Further inspection of the average cybersickness scores across the different experimental conditions revealed the following results.

Descriptives

Conditions	Mean	SD	N
SitVR	26.928	1.673	5
StandVR	22.440	2.645	5
WalkVR	17.204	2.048	5

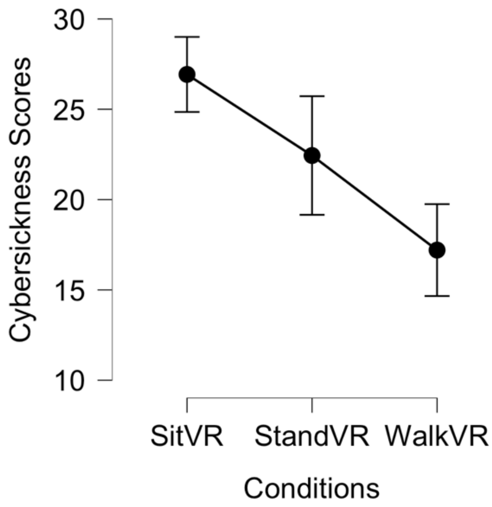


Figure 20 The change in Cybersickness scores across different experimental conditions

The results showed a steady decrease in the cybersickness scores suggesting that players' feeling of motion sickness has decreased with the progress of different experimental conditions. In order to further understand the results, we decided to use Post Hoc Tests with Holm's correction and the results are represented in the following table.

Post Hoc Comparisons - Conditions

		Mean Difference	95% CI for Mean Difference		SE	t	Cohen's d	p_{holm}
			Lower	Upper				
SitVR	StandVR	4.488	1.525	7.451	0.748	6.000	2.683	0.008 **
	WalkVR	9.724	6.095	13.353	0.916	10.614	4.747	0.001 **
StandVR	WalkVR	5.236	1.607	8.865	0.916	5.715	2.556	0.008 **

* p < .05, ** p < .01

Note. Cohen's d does not correct for multiple comparisons.

Note. P-value and confidence intervals adjusted for comparing a family of 3 estimates (confidence intervals corrected using the bonferroni method).

Table 6 Post Hoc comparisons of Cybersickness scores across different experimental conditions

The results show that very significant decreases in the cybersickness scores across all the conditions with the biggest effect occurring between SitVR and WalkVR conditions (t= 10.614, Cohen's d = 4.747, p =0.001). After all the statistical analyses that we performed, we accepted the second hypothesis.

5.1.4.3 Correlation between presence scores and cybersickness scores

For testing the third hypothesis, we decided to use a correlation matrix between presence scores and cybersickness scores, and the results are displayed in the following figure.

Pearson's Correlations

			Pearson's r	p
Presence Score	-	Cybersickness Score	-0.515 *	0.025

Note. All tests one-tailed, for negative correlation

* p < .05, ** p < .01, *** p < .001, one-tailed

Table 7 Negative correlation test between presence scores and cybersickness scores

The results from Pearson correlation indicated a significant negative correlation between cybersickness scores and presence scores (pearson's r = -0.515, p=0.025) Presence score accounting for 26.52% of the variance in cybersickness scores. As a result, we accepted the third hypothesis.

5.1.4.4 The learning style predicting presence scores

After analysing the VAK learning style questionnaire results, we ended up with 4 visual learners, 1 auditory learner, and no physical learners. Since we did not get a variety of learning styles due to our small sample size, this hypothesis could not be tested, and as a result, we could not accept our fourth hypotheses.

5.1.4.5 Correlation between pupil diameter and presence scores

For testing the fifth hypothesis, we used a correlation matrix between average pupil diameter and presence scores, and the results are displayed in the following table.

Pearson's Correlations

			Pearson's r	p
Presence Score	-	Average Pupil diameter	0.043	0.440

Note. All tests one-tailed, for positive correlation

* p < .05, ** p < .01, *** p < .001, one-tailed

Table 8 Positive correlation test between presence scores and average pupil diameter

The results from Pearson's correlation indicated no significant positive correlation between pupil diameter and presence scores (Pearson's r = 0.043, p = 0.440) Presence score accounting for 0.18% of the variance in pupil diameter. In order to understand the association between average pupil diameter and presence scores, we added a scatter plot to our analysis which is displayed in the following figure.

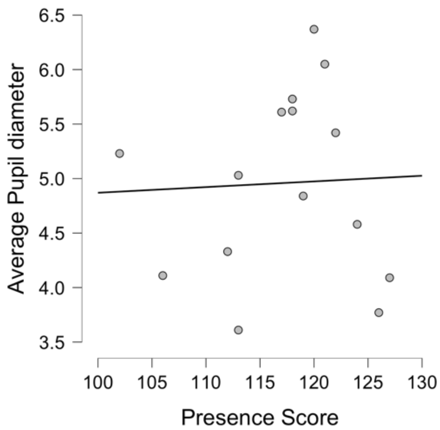


Figure 21 Visual representation of correlation between presence scores and average pupil diameter

The graph suggests no positive correlation between presence scores and average pupil diameter, and as a result we could not accept our fifth hypothesis.

5.1.4.6 Correlation between blink rate and presence scores

For our sixth hypothesis, we also used a correlation matrix between blink rate and presence scores for our statistical analysis, and the results are as the following table:

Pearson's Correlations

		Pearson's r	p
Presence Score	- Blink Rate	-0.276	0.160

Note. All tests one-tailed, for negative correlation
* p < .05, ** p < .01, *** p < .001, one-tailed

Table 9 Negative correlation test between presence score and blink rate

The results from Pearson's correlation indicated no significant negative correlation between blink rate and presence scores (Pearson's r = -0.276, p = 0.160) Presence score accounting for 7.61% of variance in blink rate. For additional analysis, we also decided to include a scatter plot to check the associations between blink rate and presence score, and the results are displayed in the following figure.

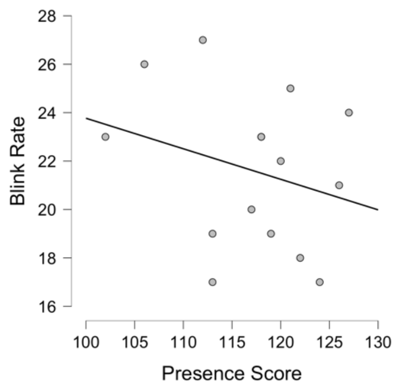


Figure 22 Visual representation of correlation between presence scores and blink rate

As suggested by the scatter plot graph, there is no significant correlation between blink rate and presence score, and as a result, we could not accept our sixth hypothesis.

5.1.4.7 Correlation between average heart rate and presence scores

Similar to our previous analysis, we used a correlation matrix between average heart rate and the presence scores in order to check the relationship between these two variables, and the results are displayed in the following table.

Pearson's Correlations

			Pearson's r	p
Presence Score	-	Average Heart Rate	0.487 *	0.033

Note. All tests one-tailed, for positive correlation
* p < .05, ** p < .01, *** p < .001, one-tailed

Table 10 Positive correlation test between presence score and average heart rate

The results from Pearson's correlation indicated that there is a significant positive correlation between presence scores and average heart rates of the players (Pearson's r = 0.487, p = 0.033) Presence score accounting for 23.71% of variance in average heart rate. We expected these results to happen because the experimental design that we implemented forced the players to exert more physical energy with every condition in order to move in the virtual world of Skyrim which will automatically increase the heart rate of our participants. Therefore, we will be investigating this hypothesis further in the second study in order to confirm whether the increase in average heart rate was caused by the increase in physical activity or it is reflecting the increase the sense of presence that the user is experiencing during the gameplay. As a result, we decided to accept our seventh hypothesis for now waiting for the results that we will get in our second study in order to confirm it or reject it.

5.1.4.8 Avatar-Identification scores

In order to interpret (H8) and analyse how the avatar-identification scores change with different experimental conditions (SitVR, StandVR, and WalkVR), we decided to use repeated measures ANOVA, and the results are displayed in the following table.

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η²
Conditions	0.097	2	0.049	5.541	0.031	0.581
Residuals	0.070	8	0.009			

Note. Type III Sum of Squares

Table 11 Repeated measures ANOVA of avatar-identification scores across different experimental conditions

The results of our test suggests a significant change in avatar-identification scores in different experimental conditions (F(2,8) = 5.541, p = 0.031 , $\boxed{\eta^2}$ = 0.581). We also decided to add some descriptive analysis to check the changes of avatar identification when moving from one experimental condition to the other, and the results are displayed in the following figure.

Descriptives

Conditions	Mean	SD	N
SitVR	3.669	0.354	5
StandVR	3.767	0.397	5
WalkVR	3.866	0.338	5

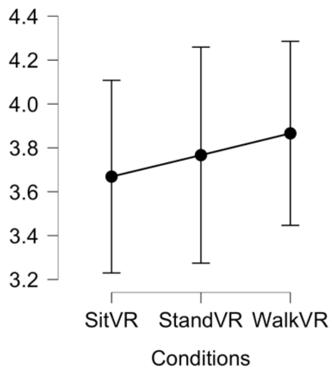


Figure 23 The change in avatar-identification scores across different experimental conditions

The results in the scatter plot shows an increase in the avatar-identification scores as we progressed through the different experimental designs that we implemented. In order to get further information about the general effect size of the change, we decided use Post Hoc Tests with Holm's correction, and the results are displayed in the following table.

Post Hoc Comparisons - Conditions

		Mean Difference	SE	t	Cohen's d	p_{holm}
SitVR	StandVR	-0.098	0.059	-1.653	-0.739	0.265
	WalkVR	-0.197	0.059	-3.329	-1.489	0.031 *
StandVR	WalkVR	-0.099	0.059	-1.676	-0.749	0.265

* p < .05

Note. Cohen's d does not correct for multiple comparisons.

Note. P-value adjusted for comparing a family of 3

Table 12 Post Hoc comparisons of avatar-identification scores across different experimental conditions

The results of the analysis shows that the only significant increase in avatar-identification scores took place between SitVR condition and WalkVR condition (t= -3.329, Cohen's d = -1.489, p = 0.031) suggesting that players developed an attachment to their character when they were able to navigate the Skyrim world by physically walking and running-in place. This suggestion was backed up by our participants comments who stated that when they were moving in place, they felt that they were transferred to their characters, and that it was them who are moving in the virtual world. As a result, we accepted our eighth hypothesis.

5.1.4.9 Correlation between presence score and avatar-identification scores

In order to assess (H9), we also used a correlation matrix between presence scores and avatar-identification scores in order to check the relationship between these two variables, and the results are displayed in the following table.

Pearson's Correlations

			Pearson's r	p
Presence Score	-	Avatar Identification Score	0.430	0.055

Note. All tests one-tailed, for positive correlation

* p < .05, ** p < .01, *** p < .001, one-tailed

Table 13 Positive correlation test between presence scores and avatar-identification scores

The results from Pearson's correlation did not indicate a significant positive correlation between presence score and avatar-identification score (Pearson'r = 0.430, p =

0.055)Presence score accounting for 18.49% of the variance in avatar-identification scores. Our result was very close to having a significant positive correlation between these two variables, and we believe that if we had a bigger sample size, the results would indicate a significant positive correlation between these two variables. We will be further investigating this hypothesis in our second study to check for significant results however the results in this study did not indicate any significance, and as a result we could not accept our ninth hypothesis.

5.1.4.10 Immersive tendencies score predicting presence scores

In order to assess (H10), we decided to implement linear regression between immersive tendency scores and our presence scores in each one of our experimental conditions. We first started by applying linear regression between the immersive tendency scores and presence scores in (Screen) condition and the results are as the following.

Model Summary - Screen presence scores

Model	R	R^2	Adjusted R^2	RMSE
H_1	0.998	0.996	0.994	7.970

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H_1	Regression	56380.942	1	56380.942	887.685	< .001
	Residual	254.058	4	63.515		
	Total	56635.000	5			

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H_1	Immersive Tendency Scores	1.056	0.035	1.838	29.794	< .001

Table 14 Linear Regression between Immersive tendency Scores and presence scores in (Screen) condition

The results of the linear regression indicated that there is a significant effect between immersive tendency scores and presence scores in (Screen) condition (F(1,4) = 887.685, $\boxed{R^2}$ = 0.996, p <0.001). Similarly, we used linear regression to test the effect of immersive tendency scores on (SitVR) presence scores, and the results are the following.

Model Summary - SitVR Presence Scores

Model	R	R²	Adjusted R²	RMSE
H_1	0.997	0.994	0.993	9.843

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H_1	Regression	65511.456	1	65511.456	676.171	< .001
	Residual	387.544	4	96.886		
	Total	65899.000	5			

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H_1	Immersive Tendency Scores	1.139	0.044	2.021	26.003	< .001

Table 15 Linear regression between Immersive tendency scores and presence scores in (SitVR) condition

The results of the linear regression indicated there is a significant effect between immersive tendency scores and presence scores in (SitVR) condition (F(1,4) = 676.171, $\boxed{R^2}$ = 0.994, p<0.001).

Applying linear regression between immersive tendency scores and presence scores in (StandVR) condition resulted in the following.

Model Summary - StandVR presence Scores

Model	R	R²	Adjusted R²	RMSE
H_1	0.996	0.993	0.991	11.084

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H_1	Regression	66721.609	1	66721.609	543.124	< .001
	Residual	491.391	4	122.848		
	Total	67213.000	5			

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H_1	Immersive Tendency Scores	1.149	0.049	2.426	23.305	< .001

Table 16 Linear regression between immersive tendency scores and presence scores in (StandVR) condition

The results of the linear regression also showed a significant effect between immersive tendency scores and presence scores in (StandVR) condition (F(1,4) = 543.124, $\boxed{R^2}$= 0.993, p <0.001). For the final linear regression test, the results are represented in the following table.

Model Summary - Walk VR presence Scores

Model	R	R²	Adjusted R²	RMSE
H_1	0.996	0.991	0.989	12.548

ANOVA

Model		Sum of Squares	df	Mean Square	F	p
H_1	Regression	72984.157	1	72984.157	463.507	< .001
	Residual	629.843	4	157.461		
	Total	73614.000	5			

Coefficients

Model		Unstandardized	Standard Error	Standardized	t	p
H_1	Immersive Tendency Scores	1.202	0.056	2.522	21.529	< .001

Table 17 Linear regression between Immersive tendency scores and presence scores in (WalkVR) condition

Similar to the previous linear regression tests, the results in this case also indicate a significant effect between immersive tendency scores and presence scores in (WalkVR) condition (F(1,4) = 463.507, $\boxed{R^2}$ = 0.991, p < 0.001).

After analysing all the linear regression tests that we performed, the results suggest that immersive tendency scores seem to predict the presence scores in all the experimental conditions, and as a result we accepted our final hypothesis.

5.2 Second Study

After the analysis that we performed in our first study, we wanted to further understand the changes of presence, cybersickness, and avatar-identification that the players experience in virtual reality. Therefore, we decided to conduct a second study that will further confirm our hypotheses or reject them. The aim of this study is to study the changes in our dependent variables over one week of playing the game and to check the variation of these scores in the long-term rather than having an experiment that is done in one day.

5.2.1 Experimental Design

In this study, we will not be using different experimental conditions as independent variable, but we will be only using the last condition (WalkVR) for the full span of the experiment that lasts for one week. Our participants will be the same participants that participated in the first study where they will continue playing their saved games progress for 1 hour each day for a period that lasts for 7 days under the (WalkVR) condition. The post-session procedure will be the same as the post-condition procedure that was implemented in the first study where participants have to fill the questionnaires in order to get their presence, cybersickness, and avatar-identification scores.

5.2.2 Experimental Procedure

In this section, we will be discussing the step by step procedure in implementing our second study. Most of the steps taken are identical to the steps that we took in the first study. The list of steps that we took with each participant was carried out as the following:

1- We called our participant and informed him that we need him to participate in our second study where he had to play one hour of SkyrimVR for 7 days. We informed him that these days do not have to be consecutive, and that he can show up in his free time to enjoy one hour gaming session, and that he will be using his saved game progress that he used in the last study, so he can enjoy the continuation of his Skyrim story.

2- After the arrival of the participant, we gave him a brief reminded of our experiment even though most of them did not need it since they were so familiar with the experiment.

3- The participant was then asked to attach the Bluetooth heart rate sensor to his chest using the straps that we provided.

4- After that, we attached the Vive trackers to the ankle of our participants using the straps, and then we linked them to our desktop and activated the walk-in-place functionality in Natural Locomotion software.

5- We opened SteamVR dashboard and performed eye calibration for our participant in order to get accurate eye data tracking.

6- After that, we gave a reminder of the movement system to the participant and told him that they had to run and walk in place in order to navigate the game world.

7- When everything was clear, we guided the participant to the play space in the middle of the room, and we started the modded SkyrimVR with Natural Locomotion software.

8- We loaded the previously saved game of the participant and ran the eye logger in order to keep track of all the eye data.

9- We started the 1 hour session timer, and at the end, the participant was asked to fill the same post-condition questionnaires that were used in the previous study while we recorded the average heart rate using the Elite HRV mobile in addition to the average pupil diameter and blink rate using the recorder eye logger data.

The same process took place for the remaining six days of the experiment, and by the end of the last day, we asked the participant to fill the self-perception questionnaire again which will be used in the discussion section to analyse how this long-term experiment changed their self-perception.

During the experimentation process, we also used the same stopping criteria that was implemented in the first study in case something unexpected occurred during the experimentation process.

5.2.3 Hypotheses:

In this study, the hypotheses that we are going to analyse are very similar to our last set of hypotheses, but in this study, we are analysing the hypotheses over extended periods of time and using one fixed experimental condition (WalkVR). The list of hypotheses that we are going to analyse are as the following:

(H1) The presence scores of the players will increase after each gaming session during the experimentation days.

(H2) Avatar-Identification scores will increase after each gaming session during the experimentation days.

(H3) Cybersickness scores will decrease after each gaming session during the experimentation days.

(H4) Cybersickness scores will negatively correlate with presence scores.

(H5) Avatar-identification scores will positively correlate with presence scores.

(H6) Average heart rate will positively correlate with presence scores.

(H7) Pupil diameter will positively correlate with presence scores.

(H8) Blink rate will negatively correlate with presence scores.

5.2.4 Results

In this section, we will be discussing the statistical analysis that we used in order to assess our hypotheses. We evaluated the same participants who participated in our first study where the sample size N = 5, all the participants are males, and the average age of the sample is 25.8.

5.2.4.1 Presence Scores

In order to assess (H1) and analyse the change in presence scores across the different experimental days, we used the same statistical analysis test that we used in our first study which is the repeated measures ANOVA. The results are represented in the following table.

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Days	439.943	6	73.324	57.455	< .001	0.935
Residuals	30.629	24	1.276			

Note. Type III Sum of Squares

Table 18 Repeated measures ANOVA of presence scores across different experimentation days

The results of the test suggest a very significant change in presence scores across the 7 experimentation days ($F(6,24) = 57.455$, $p < 0.001$, $\boxed{\eta^2} = 0.935$). Again, we did deeper analysis to check how the average presence scores change across the 7 days and the results are represented in the following figure.

Descriptives

Days	Mean	SD	N
Day 1	121.200	6.301	5
Day 2	122.800	5.541	5
Day 3	125.400	5.941	5
Day 4	127.200	5.215	5
Day 5	128.000	4.950	5
Day 6	130.800	5.310	5
Day 7	131.400	4.615	5

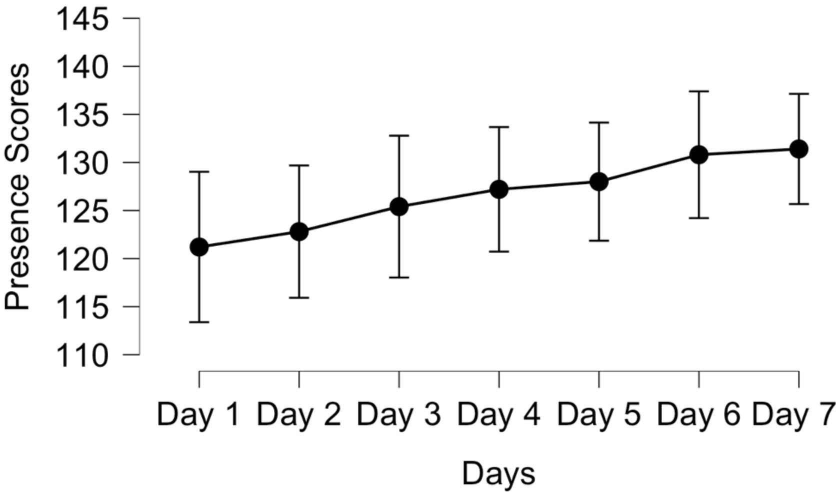


Figure 24 Change in presence scores across different experimentation days

Once again, the results indicate a continuous increase in average presence scores across different experimentation days. We also decided to use Post Hoc Tests with Holm's correction to check the significant changes of presence scores across experimentation days and to check the effect sizes of these changes. The results are represented in the following table.

Post Hoc Comparisons - Days

		Mean Difference	SE	t	Cohen's d	p_{holm}
Day.1	Day.2	-1.600	0.748	-2.138	-0.956	0.298
	Day.3	-4.200	0.800	-5.250	-2.348	0.038 *
	Day.4	-6.000	0.707	-8.485	-3.795	0.014 *
	Day.5	-6.800	1.020	-6.668	-2.982	0.024 *
	Day.6	-9.600	0.927	-10.352	-4.630	0.008 **
	Day.7.	-10.200	1.241	-8.219	-3.676	0.014 *

Post Hoc Comparisons - Days

		Mean Difference	SE	t	Cohen's d	p_{holm}
Day.2	Day.3	-2.600	0.245	-10.614	-4.747	0.008 **
	Day.4	-4.400	0.678	-6.487	-2.901	0.024 *
	Day.5	-5.200	0.735	-7.076	-3.165	0.022 *
	Day.6	-8.000	0.632	-12.649	-5.657	0.004 **
	Day.7.	-8.600	0.927	-9.274	-4.147	0.012 *
Day.3	Day.4	-1.800	0.735	-2.449	-1.095	0.282
	Day.5	-2.600	0.748	-3.474	-1.554	0.127
	Day.6	-5.400	0.600	-9.000	-4.025	0.013 *
	Day.7.	-6.000	0.949	-6.325	-2.828	0.024 *
Day.4	Day.5	-0.800	0.374	-2.138	-0.956	0.298
	Day.6	-3.600	0.400	-9.000	-4.025	0.013 *
	Day.7.	-4.200	0.583	-7.203	-3.221	0.022 *
Day.5	Day.6	-2.800	0.200	-14.000	-6.261	0.003 **
	Day.7.	-3.400	0.245	-13.880	-6.208	0.003 **
Day.6	Day.7.	-0.600	0.400	-1.500	-0.671	0.298

Note. P-value adjusted for comparing a family of 21

Note. Cohen's d does not correct for multiple comparisons.

* $p < .05$, ** $p < .01$

Table 19 Post Hoc comparisons of presence scores across different experimentation days

The results from our Post Hoc Test Analysis showed continuous increase across different experimental days, but the biggest score change occurred between day 5 and day 6 (t = -14, Cohen’s d = -6.261, p =0.003), and between day 5 and day 7 (t= -13.880, Cohen’s d = -6.208, p = 0.003) suggesting that players were experiencing a boost in their state of presence towards the later days of the experiment. As observers, we noticed that the participants became very comfortable with the game when they got so used to the game to the point that it did not feel like an experiment anymore, but it felt like a player enjoying playing the virtual world of Skyrim. Furthermore, the participants’ comments at the end of the experiment suggested the same results where they expressed that the more they played, the more the game opened up with features and became so addictive. They were pleased with the huge number of features that the game offered from customisation to decision making, and this was reflected in their presence scores towards the later days of the experiment where they became addicted to the virtual world and more engaged in it. After all the analysis that we have done, we accepted our first hypothesis.

5.2.4.2 Avatar-Identification Scores

For assessing (H2), we also used the same statistical analysis that we used in our previous study in order to check for the change how the avatar-identification scores changed across different experimentation days. For this assessment, we used repeated measures ANOVA across different experimentation days, and the results are as the following.

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Days	1.125	6	0.187	15.457	< .001	0.794
Residuals	0.291	24	0.012			

Note. Type III Sum of Squares

Table 20 Repeated measures ANOVA of avatar-identification scores across different experimentation days

The results also suggest a very significant change in avatar-identification scores across the experimentation days ($F(6,24) = 15.457$, $p < 0.001$, $\eta^2 = 0.794$). Further analysis indicated that the average identification scores is increasing with every experimentation day, and the results are represented in the following figure.

Descriptives

Days	Mean	SD	N
Day 1	3.983	0.379	5
Day 2	4.016	0.397	5
Day 3	4.101	0.389	5
Day 4	4.201	0.372	5
Day 5	4.267	0.310	5
Day 6	4.401	0.260	5
Day 7	4.500	0.170	5

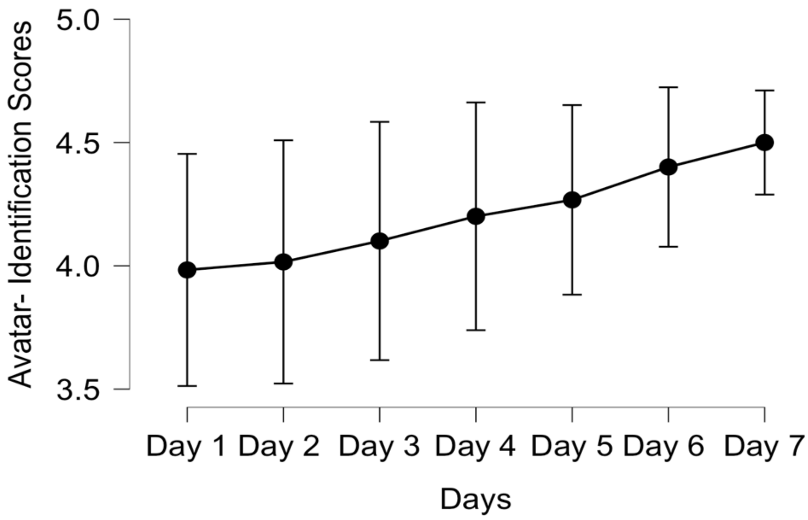


Figure 25 Change in avatar-identification scores across different experimentation days

We also used Post-Hoc Tests with Holm's correction in order to check the significant changes in Avatar-Identification score from one experimentation day to the other, and we also we wanted to understand the effect size of these changes. The results are displayed in the table below.

Post Hoc Comparisons - Days

		Mean Difference	SE	t	Cohen's d	p holm
Day.1	Day.2.	-0.033	0.070	-0.468	-0.209	0.818
	Day.3	-0.117	0.070	-1.686	-0.754	0.629
	Day.4	-0.217	0.070	-3.123	-1.396	0.051
	Day.5	-0.284	0.070	-4.080	-1.825	0.006 **
	Day.6.	-0.417	0.070	-5.993	-2.680	< .001 ***
	Day.7	-0.517	0.070	-7.420	-3.319	< .001 ***
Day.2.	Day.3	-0.085	0.070	-1.218	-0.545	0.818
	Day.4	-0.185	0.070	-2.655	-1.187	0.125
	Day.5	-0.252	0.070	-3.612	-1.615	0.018 *
	Day.6.	-0.385	0.070	-5.525	-2.471	< .001 ***
	Day.7	-0.484	0.070	-6.952	-3.109	< .001 ***
Day.3	Day.4	-0.100	0.070	-1.437	-0.643	0.818
	Day.5	-0.167	0.070	-2.394	-1.071	0.199
	Day.6.	-0.300	0.070	-4.308	-1.926	0.004 **
	Day.7	-0.399	0.070	-5.735	-2.565	< .001 ***
Day.4	Day.5	-0.067	0.070	-0.957	-0.428	0.818
	Day.6.	-0.200	0.070	-2.871	-1.284	0.084

Post Hoc Comparisons - Days

		Mean Difference	SE	t	Cohen's d	p_{holm}
	Day.7	-0.299	0.070	-4.298	-1.922	0.004 **
Day.5	Day.6.	-0.133	0.070	-1.913	-0.856	0.474
	Day.7	-0.233	0.070	-3.341	-1.494	0.033 *
Day.6.	Day.7	-0.099	0.070	-1.427	-0.638	0.818

Note. P-value adjusted for comparing a family of 21

Note. Cohen's d does not correct for multiple comparisons.

* p < .05, ** p < .01, *** p < .001

Table 21 Post Hoc comparisons of avatar-identification scores across different experimentation days

The results from our Post Hoc Tests shows significant increases in avatar identification scores after each gaming session during the experimentation days with the most significant increase occurring between day 1 and day 7 ($t = -7.420$, Cohen's $d = -3.319$, $p < 0.001$). These results were backed up by the participants' comments where they expressed that they were getting more attached to their characters as the game progressed and gave them lots of options to customise him from items to decision making to choosing suitable skills that they wanted to equip their character with. The participants also believed that their connection with the character increased as the game provided them with more options to customise him or her. Based on all the statistical analysis that we have done; we accepted our second hypothesis.

5.2.4.3 Cybersickness Scores

The same statistical analysis approach was taken for assessing (H3) the change in cybersickness scores after each gaming session during the experimentation days, and the results for the repeated measure ANOVA results are represented in the following figure.

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p
Days	2426.649	6	404.441	47.811	< .001
Residuals	203.020	24	8.459		

Note. Type III Sum of Squares

Table 22 Repeated measures ANOVA of cybersickness across different experimentation days

The results suggest a very significant change in cybersickness scores across our experimentation days($F(6,24) = 47.811$, $p < 0.001$). Further analysis also indicated that cybersickness scores were decreasing with every passing experimentation day, and the results are represented in the following figure.

Descriptives

Days	Mean	SD	N
Day 1	32.912	3.129	5
Day 2	28.424	2.048	5
Day 3	26.928	3.129	5
Day 4	24.684	4.264	5
Day 5	20.196	4.264	5
Day 6	11.968	5.547	5
Day 7	8.228	4.097	5

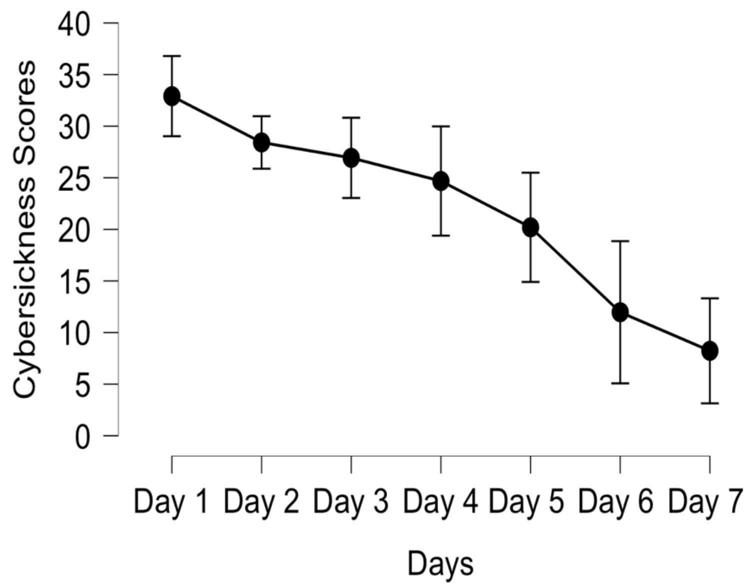


Figure 26 The change in cybersickness scores across different experimentation days

We also used Post Hoc Test with Holm's correction to investigate the significant changes in cybersickness scores from one gaming session to the other, and the results are represented in the following figure.

Post Hoc Comparisons - Days

		Mean Difference	SE	t	Cohen's d	p_{holm}
Day.1	Day.2	4.488	0.748	6.000	2.683	0.054
	Day.3	5.984	1.496	4.000	1.789	0.113
	Day.4	8.228	1.399	5.880	2.630	0.054
	Day.5.	12.716	0.916	13.880	6.208	0.003 **
	Day.6.	20.944	1.496	14.000	6.261	0.003 **
	Day.7.	24.684	1.907	12.944	5.789	0.004 **
Day.2	Day.3	1.496	0.916	1.633	0.730	0.356
	Day.4	3.740	1.183	3.162	1.414	0.205
	Day.5.	8.228	1.399	5.880	2.630	0.054
	Day.6.	16.456	1.907	8.629	3.859	0.016 *
	Day.7.	20.196	1.907	10.590	4.736	0.008 **
Day.3	Day.4	2.244	0.916	2.449	1.095	0.282
	Day.5.	6.732	2.181	3.087	1.381	0.205
	Day.6.	14.960	2.645	5.657	2.530	0.054
	Day.7.	18.700	2.645	7.071	3.162	0.032 *
Day.4	Day.5.	4.488	1.832	2.449	1.095	0.282
	Day.6.	12.716	2.244	5.667	2.534	0.054
	Day.7.	16.456	3.038	5.416	2.422	0.054
Day.5.	Day.6.	8.228	0.748	11.000	4.919	0.007 **
	Day.7.	11.968	2.181	5.488	2.454	0.054
Day.6.	Day.7.	3.740	2.365	1.581	0.707	0.356

Note. P-value adjusted for comparing a family of 21

Note. Cohen's d does not correct for multiple comparisons.

* $p < .05$, ** $p < .01$

Table 23 Post Hoc comparison of cybersickness scores across different experimentation days

The results showed continuous decrease in cybersickness score after each day, and the most significant decrease cybersickness score occurred between day 1 and day 7 (t = 14, Cohen's d = 6.261, p =0.003). These results are supported by the participants' comments who said that during the first couple of days they were feeling a lot of motion sickness while they were playing the game, and they thought that their body was not compatible with the VR experience however their motion sickness started decreasing with every passing gaming session. We also noticed that towards the end of the experiment, the only two symptoms of cybersickness that were reported by most of the participants are sweating and general discomfort which indicates that most of the other symptoms that were reported at the earlier stages of the experimentation were gone as had more gameplay time. After all the analysis that we have done, we also accepted our third hypothesis.

5.2.4.4 Correlation between cybersickness scores and presence score

In order to assess (H4), we used a correlation matrix between cybersickness score and presence scores, and the results are displayed in the following table.

Pearson's Correlations

	Pearson's r	p
Presence Score - Cybersickness Score	-0.333 *	0.025

Note. All tests one-tailed, for negative correlation
* p < .05, ** p < .01, *** p < .001, one-tailed

Table 24 Negative correlation test between presence scores and cybersickness scores in the second study

The results from Pearson's correlation indicated a significant negative correlation between presence scores and cybersickness scores (Pearson's r =-0.333, p =0.025) Presence score accounting for 11.08% of variance in cybersickness scores. The results are represented in the following scatter plot.

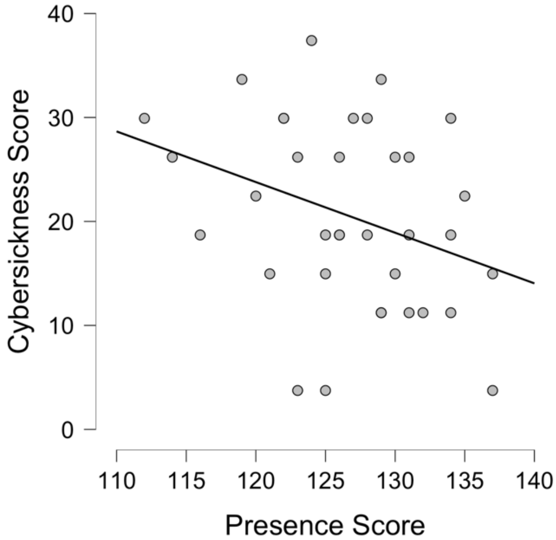


Figure 27 Visual representation of correlation between presence scores and cybersickness scores in the second study

The result matches with the result that we had in the first study, and it adds additional evidence to support the negative relationship between presence scores and cybersickness scores. Therefore, we accepted our fourth hypothesis.

5.2.4.5 Correlation between presence scores and avatar-identification scores:

For assessing (H5), we used a correlation matrix between presence scores and avatar-identification scores, and the results are represented in the table below.

Pearson's Correlations

		Pearson's r	p
Presence Score	- Avatar Identification Scores	0.382 *	0.012

Note. All tests one-tailed, for positive correlation

* p < .05, ** p < .01, *** p < .001, one-tailed

Table 25 Positive correlation test between presence scores and avatar-identification scores in the second study

The results showed a significant positive correlation between presence scores and avatar-identification scores (Pearson's r = 0.382, p = 0.012) Presence score accounting for 14.59% of variance in avatar-identification score. The results are represented in the following scatter plot.

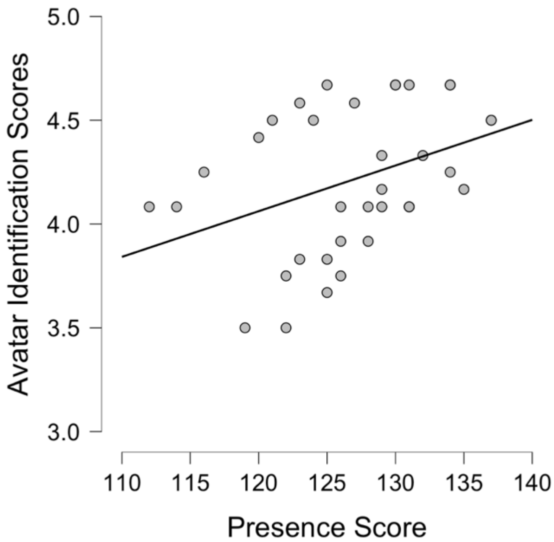


Figure 28 Visual representation of correlation between presence scores and avatar-identification scores in the second study

The result that we got in this study were different to those that we got in the first study where in the first study, we did not get any significant positive correlation between avatar-identification scores and presence scores however we stated that we expected a significant positive correlation between those two variables in case we have a bigger sample data size, and our assumption was confirmed in this study where we were able to extract more presence scores and avatar-identification scores from our participants over several experimentation days. For all the reasons mentioned, we accepted our fifth hypothesis.

5.2.4.6 Correlation between average heart rate and presence scores

Same statistical analysis test was used to assess (H6) in order to test the correlation between average heart rate and presence scores, and the results are displayed in the table below.

Pearson's Correlations

			Pearson's r	p
Presence Score	-	Average Heart Rate	0.018	0.460

Note. All tests one-tailed, for positive correlation

* p < .05, ** p < .01, *** p < .001, one-tailed

Table 26 Positive correlation test between presence scores and average heart rate in the second study

The results from Pearson's r correlation test showed no significant positive correlation between presence scores (Pearson'r = 0.018, p =0.460) Presence score accounting for 0.0324% of variance in average heart rate. The results are represented in the following scatter plot.

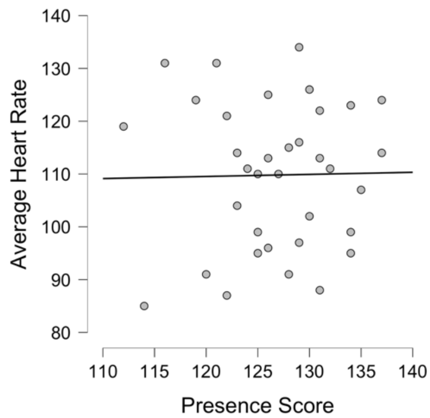


Figure 29 Visual representation of correlation between presence scores and average heart rates

Our results are different from the results that we got from our first study although we stated that in the first study results that the different experimental conditions force players to exert additional physical activity with each experimental condition, and as a result the heart rate was positively correlating with presence scores. On the other hand, in this study, we only had one experimental condition (WalkVR), making the results in this experiment a more accurate representation of the relation between heart rate and presence scores. Since the result showed no significant correlation and a very low Pearson's r coefficient, we cannot accept the assumption that presence scores and average heart rates are positively correlated, and we cannot accept our sixth hypothesis.

5.2.4.7 Correlation between pupil diameter and presence scores:

For evaluating (H7), we used the same statistical test between for pupil diameter and presence scores variables, and the result are represented in the following table.

Pearson's Correlations

			Pearson's r	p
Presence Score	-	Average Pupil Diameter	-0.121	0.755

Note. All tests one-tailed, for positive correlation
* p < .05, ** p < .01, *** p < .001, one-tailed

Table 27 Positive correlation test between presence scores and average pupil diameter

The results from Pearson's r correlation test showed no significant positive correlation between pupil diameter and presence scores (Pearson's r = -0.121, p = 0.755) Presence score accounting for 1.46% of variance in average pupil diameter. The results are represented in the following scatter plot.

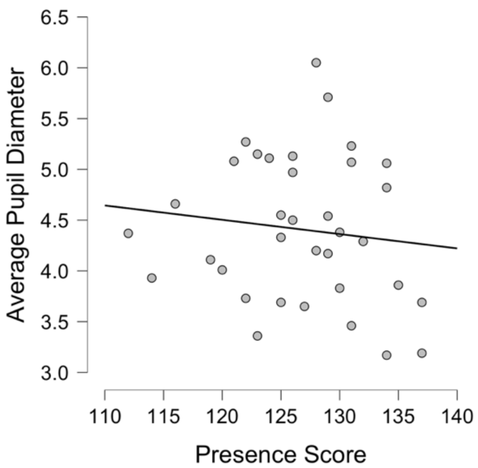


Figure 30 Visual representation of correlation between presence scores and average pupil diameter

We assumed that we will have a constant increase in pupil diameter size with the increase in presence scores due to the increased involvement and absorption that the players experience while they are playing the Skyrim game. However, the results did not reflect our assumption, and the Pearson's r coefficient indicated that the relation between presence scores and average pupil diameter was closer to be a negative relation rather than a positive relation. As a result, we could not accept our seventh hypothesis.

5.2.4.8 Correlation between blink rate and presence Scores

We used the same test that was used previously to test (H8) and check the correlation between blink rate and pupil diameter, and the results are represented in the following table.

Pearson's Correlations

		Pearson's r	p
Presence Score	- Blink Rate	0.059	0.632

Note. All tests one-tailed, for negative correlation

* p < .05, ** p < .01, *** p < .001, one-tailed

Table 28Negative correlation test between presence scores and blink rate in the second study

The results from Pearson' r correlation test did not show any significant negative correlation between the players' blink rates and their presence scores (Pearson's r = 0.059, p = 0.632) Presence score accounting for 0.34% of change in blink rate. The results are represented in the following scatter plot.

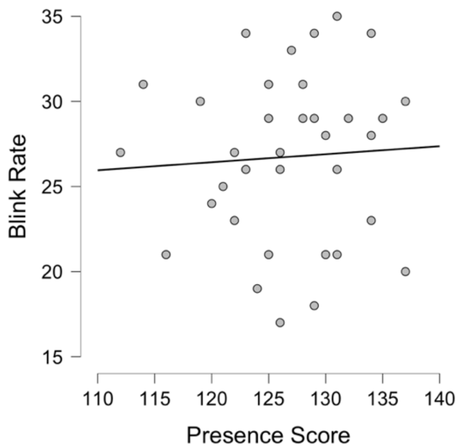


Figure 31Visual representation of correlation between presence scores and blink rate

We assumed that a high blink rate is a sign of discomfort and tiredness, and as a result with higher presence scores, we expected lower blink rates. However, the results did not reflect our hypothesis, and as a result we could not accept our final hypothesis.

5.3 Discussion:

5.3.1 Presence:

One of the main important aims of our experiment is to implement a system in virtual reality where the user would achieve a sustainable and continuously increasing state of presence, and our results suggested that we were close to achieving our goal, so we wanted to discuss the elements of our study that allowed our players to achieve this state and increasing their presence scores as the gameplay progressed. Here is a list that we believe helped in implementing such this system based on our statistical analysis and the players feedback after both of the studies were done.

1- **Implementing the natural locomotion walk-in place mechanic for movement in the game**:

Our analysis of presence scores shows the boost in presence scores among participants when the walk-in place natural locomotion functionality was implemented as a way to move in the Skyrim world. In addition to that, our participants provided us with a very positive feedback regarding this mechanic where they stated that having their physical bodies move in place in order to move in the virtual world was very helpful in decreasing the motion sickness that they experienced at the beginning of the experiment, and it added a new level of immersion to the game and made it feel like a completely new game experience. Additionally, some of them expressed that they lost track of time while they were playing the game, and they did not feel like they have been walking or running in place for an hour, and they believed that this might be a solution for their lack of walking exercises in real life because they used to get bored easily. All our analysis shows that this mechanic is very effective in achieving high states of presence in the players and sustaining such state in the long term.

2- **Visual Improvement in the game**:

Another element that helped in achieving a continuous state of presence is the visual improvement that we implemented in the Skyrim game which confirms the studies previous in the field of presence that claims that visual fidelity is an important factor in achieving high states of presence (Kaul et al., 2017). This was confirmed by our participants when they described the scenery in the game as very impressive and realistic that they had to stop and admire the views with each new scene that was introduced to the game as the game progressed.

3- **Customisability and non-repetitive gameplay**:

Other elements that help in improving the state of presence in the game were stated by our participants in their comments and qualitative feedback. One of these elements is the ability to customise everything about the participant’s character like items, weapons, looks, skills, and decision making. Another element of immersion that was pointed out by our participant was the non-repetitive gameplay where our participants enjoyed the fact that the more they played, the game opened up more and more with items, quests, and decisions to make which made them enjoy the game a lot and sustain a state of presence in the virtual world.

5.3.2 The relation between avatar-identification and presence

Another important part in our study was to analyse the relation between the degree to which our players connect and identify with their characters and how such connection affects the state of presence that the player is experiencing in the virtual reality world. We measured the avatar-identification scores based on three subscales which are liking, physical similarity, and wishful identification. The results in both of our studies showed that our participants were developing a bond with their character, and they were able to identify more with it as they played the game for extended period of times with each session increasing their avatar-identification scores. In addition to that, our second study showed a significant positive correlation between avatar-identification scores and presence scores which suggested that players are more likely to improve their state of presence and immersion when they are connected to the character that they are controlling in the game. This assumption was supported by the significance of our statistical analysis and by the participants comments by the end of the experimentation where they were expressed with each session they felt like they were becoming the character that they were playing in the game, and they felt like they were navigating the world which was very immersive experience for them.

5.3.3 The relation between cybersickness and presence

In our related study section, we deeply discussed the issues of cybersickness and referred to the previous studies that covered the relation between cybersickness and presence in virtual reality. Most of the previous literature indicated that there is a negative correlation between the state of presence and cybersickness in virtual reality however there were also some studies that pointed out that there is a positive correlation between these two variables. In both of our experiments we found that there was a negative correlation between presence and cybersickness, and the cybersickness scores was always decreasing as the players were getting more virtual reality experience. The cybersickness scores of our participants was continuously decreasing from session in both of our studies which agrees with the findings of most of the prior findings that covered this topic. In addition to that, our analysis showed that the implementation of natural locomotion walk-in place functionality was a major cause for the decrease in cybersickness scores where in our first study, there was significant decrease in cybersickness scores once the walk-in place functionality was applied to the game. This assumption was backed up by the participants comments who also believed that implementing this mechanic helped a lot in decreasing the motion sickness that they were experiencing during their gaming sessions, and they also expressed that most of the discomfort that they were having during the experiment seemed to decrease with each passing gaming session during our second experiment, and that allowed them to get a better gaming experience and achieving higher level of immersion.

5.3.4 Learning style affecting presence

In our related studies section, we mentioned that previous literature has stated that visual learners are more likely to experience a state of presence in virtual reality compared to auditory learners and physical learners (Schubert, 2001). We wanted to check if that assumption would apply to our sample and experiment, but unfortunately, we had a very small sample size, and we could not test this hypothesis. We weren't able to find a larger number of participants for our experiment, and we ended up with 4 visual learners, one auditory learner, and no physical learners. Due to the lack of data that we could gather, we could not test the effect that learning styles on the state of presence that the user experience during virtual reality sessions.

5.3.5 Immersive tendency qualities and traits affecting presence

In our related studies section, we discussed different factors and traits that might affect the sense of presence that the user experiences during virtual reality experience, and in order to study the effect that these characteristics have on the presence scores of the users, we asked our participants to answer an immersive tendency questionnaire. This questionnaire provided us with an immersive tendency score which was based on different subscales that were proved to be effective in predicting presence by the previous literature. These subscales are empathy, introversion, absorption, ability to construct mental models, spatial orientation, active involvement, and level of gaming experience. In order to analyse these effects, we performed 4 linear regression tests between immersive tendency scores and presence scores in each of the experimental conditions, and the results showed significant effects. Therefore, our two experiments showed that immersive tendency characteristics and traits do indeed affect presence scores and the degree to which a player experiences a sense of presence in the virtual reality experience.

5.3.6 Objective physiological measurements relation with presence

Another important aim for our study was trying to find correlations and relations between objective physiological measurements and the state of presence in virtual reality. Unfortunately, we could not detect any significant correlations in our study, and in this section, we will discuss the reasons that might have led to such results.

For the average pupil diameter measurement, we assumed that we were getting a positive correlation between pupil diameter and presence. We predicted that as the player get more immersed in the game and experience an increase state of presence, his pupil diameter will also increase. This assumption was based on previous studies that showed that pupil diameter increases when users are mentally interested and invested with the task that they are performing. In addition to that these studies showed that pupil diameter increases with absorption (Lin et al., 2001), and as a result we predicted that with increased presence and immersion, the pupil diameter would increase. However, the results did not show a positive correlation between pupil diameter and presence score, and this might have happened because we did not account for other variables that might a have a significant effect on the average pupil diameter size. For example, a study done by Brendan John (2001), showed that the pupil diameter sizes changes depending on the lightning in the scene, and as we already established, Skyrim is an open world game where lightning changes a lot depending on the scene and daytime. Another study showed that the pupil diameter size changes drastically as an effect of the depth of the objects that are present in the virtual reality scene (Iskander et al., 2019), and the world in Skyrim world contains many objects with different depths which might have caused the fluctuations in the pupil diameter. Hence, we could argue that maybe adding constraints to the scenes in the game could have maybe produced a better correlation between the two variables.

For the blink rate measurement, we assumed that we were going to get a significant negative correlation between presence scores and blink rate because blink rate is considered to be sign of tiredness, fatigue, and disinterest (Stern et al., 1994). Hence, we predicted that with the increase in the state of presence and immersion that the user experiences in VR, we would get a decrease in the blink rate. Contrary to our expectation, we did not get any significant negative correlation between presence scores and blink rate which suggests that there are other factors that contributed to having no significant correlation between these two variables. The first reason is that most of the gaming sessions that were conducted during the second study were done during the night where participants participated in the study after finishing their respective jobs, and they were already which might explain the increased blink rate that the users were experiencing. Another factor that we observed during the gameplay is that the design of Skyrim game had lots of visual effects and projectiles on the screen, and as the players progressed through the game, they faced stronger enemies which might explain the increase in the number of blinks that the users are experiencing.

As for the relation between average heart rate and presence, we assumed that heart rate will positively correlate with presence and immersion as suggested by previous studies (Malinska et al., 2015). After our first study, we detected a significant positive correlation between presence scores and heart rate however we understood that the natural design of the experiment forced players to exert additional activities to move in the world of Skyrim, and as a result we could not state that heart rate positively correlate with heart rate without additional studies to be done. With this in mind, we conducted our second hypothesis and re-tested the same hypothesis, and the results did not show any significant positive correlations between heart rate and presence scores, and we believe these results are more accurate in representing the relationship between heart rate and presence variables because we did not change any independent variables during this study, and the conditional experiment was kept the same throughout all the experimentation days. We believe that in order to detect a relation between these two variables, a more constrained experiment should be conducted because our experiment had lots of variables that might have affected the heart rate readings during the experiment. For example, during the second study, we noticed that some of the participants were always moving and discovering new places in the game while others did not move a lot where they spend lots of items checking out details and reading items descriptions and characters lore. This observation made it obvious that the experiment had lots of variables that might affect heart rate where some participants would move a lot during the one hour playtime while others would not, and we realized that the freedom that we gave our participants in playing the game hindered our ability to check for correlations between heart rate and the state of presence that the users were experiencing.

5.3.7 Effects of participating in our experimentation on self-perception

As part of our two studies, we asked our participants to fill the self-perception questionnaire for a second time after finishing both of the experiments in order to get some additional information about how participating in this affected their self-perception. The results have showed some improvements in the different self-perceptions categories. For example, we noticed an improvement in the participants' believes in their ability to achieve certain goals that they set. Also, we noticed some improvements in participants' beliefs in overcoming challenges and performing effectively in different tasks. In addition to that, we also noticed that this experiment improved some of the participants' beliefs about the importance of physical activity and we had one participant commenting that he was always getting bored when he goes for walks, and he believed that if he invested in a setup that was similar to ours, he might solve the problem by walking in place while playing Skyrim. Overall, we believe that our experiment left our participants with a positive attitude.

5.4 Limitations

Although we have achieved lots of significant results in our two studies, there are still lots of limitations which could have potentially impacted the quality of our results. The first limitation is the small number of participants that we were able to gather for our experimental study where we were only able to get 5 participants due to the COVID-19 spread worldwide. Another issue to consider is that I personally participated in the experiment as one of the five participants in our experiment just to add to the pool of participants who were able to participate. Also, the other 4 participants were people who had personal connections with me, and that could raise the possibility of having some biased answers in the subjective questionnaires since they were familiar with my experimental study. In addition to that, there was little variety in the sample that we had for this study where all the participants were males and all of the participants were between the age of 20 to 32 years old, so there is a possibility of not being able to replicate these results with a sample of different genders and variety of age groups.

Another issue is that the whole experiment was conducted in a very small bedroom since we could not access the lap with decent area and space to conduct the experiment. In addition to that, the limited size of the room did not allow us to set up the head mounted display accessories properly as suggested by the instructions manual, so we had to use the bedroom accessories to find proper placement for the base stations in the room. Furthermore, the limited space could have affected the quality of the experience especially when it comes to sweating and cybersickness where people have limited space to rotate during the experiment. We also had some comments from the participants where they acknowledged that having more space would have been a preferable experience for them.

Another limitation to point out is the fact that the original plan for our second study was that each gaming session would last for about 4 hours in order to acquire more details about the long-term experience that the players are having in the modded Skyrim VR that we setup. However, due to the unfortunate circumstances, we had to lower the daily game sessions to 1 hour in order to accommodate the second study and the busy schedule of our participants.

Finally, there is one more limitation that was pointed out by the participants at the end of the experiment which is the fact that our experimental design asks the participants to fill the same questionnaires lots of times throughout the two studies, and the participants expressed that they got bored from filling the same questionnaires lots of times. This issue raises concerns about the accuracy of the subjective measurement scores and how accurate these measurements were in presenting the participants' presence, avatar-identification, and cybersickness states.

Chapter 6

Conclusion

As our project reaches the end, we are going to brief summary about the contributions that we managed to achieve. After that we will state some of the future directions of the project finishing up with my personal thought and experience while working on this project.

6.1 Contributions

Our first contribution is that we were able to enhance our understanding about the state of presence in virtual reality, and we were able to extract lots of elements that will help in improving the state of presence in short and long-term. Therefore, we could use these elements and implement in future virtual reality experiences and games in order to give the user a very positive immersive experience where they will be able to be teleported into the virtual world.

Our second contribution is that we were able to show the effect of implementing walk-in place locomotion functionality on the state of presence in both short-term and long-term. The implementation of this functionality was received positively by our participants, and it tremendously improved their presence score in both of our studies. We also discussed how such mechanic had a positive impact on our participants' self-perception.

Our third contribution is that we were able to add additional support to the studies that showed a negative correlation relation between presence and cybersickness in virtual reality. We also showed the significant effect that implementing walk-in place functionality had in decreasing cybersickness that the user experience by implementing a very thorough experimental design that showed the decreases in cybersickness score from one condition to the other.

Our fourth contribution is that we were able to provide deeper understanding about the ways that virtual reality users identify with their avatar, and we discussed lots of elements that made the user increase their bond and attachment with their characters which will help in designing future virtual reality games. In addition to that we were able to find positive correlations between avatar-identification scores and presence scores which supports the assumption that players tend to sustain an increased state of presence as they get more attached to their in-game avatar.

Unfortunately, we were not able to make any significant contribution in terms of objective measurement where our results did not show any significant correlations between objective physiological measurement and presence score. Such results could be caused because there were lots of gameplay variables that seemed to affect the object measurement, so designing a new experiment with more constraints in terms of objectives and gameplay could result in some significant relations between objective physiological measurements and the state of presence that users experience during virtual reality.

6.2 Future Works

Our project offers lots of room for improvement in future work especially in terms of applying natural locomotion walk-in place functionality in VR projects other than Skyrim and testing if the results that we got could be replicated in other games and applications.

Another contribution that our project has managed to achieve is improve our understanding about presence and we were able to extract lots of elements from our experiment that seemed to improve the sense of presence and immersion that our participants were experiencing during our experiment. It would be interesting to apply all this information to a new game that is smaller in scale compared to Skyrim and analyse the sense of presence that the users experience, and we would be able to compare the results from both of the studies.

In addition to that, our experiment was lacking in terms of participants' sample size and variety in terms of gender and age variety. As a result, it would be interesting to conduct a study that is similar to the design of our study on a bigger sample of participants with variety in genders, age groups, and cultural background. After that we could check if the results would match with the results that we got in our study which would provide more support to the hypotheses that we accepted in our study.

In terms of the correlations between objective measurements and the state of presence that the users experience in virtual reality, future studies could focus on designing experiments that are more constrained in terms of the scale of the gameplay scenes in the virtual reality unlike Skyrim which is huge in terms of scale and gameplay. Having a more constrained setup and gameplay would decreases the possibility of having gameplay variables that could affect the physiological objective measurements of the participants. Additionally, other studies could also focus on other physiological measurements like eye gaze, brain activity, and skin conductivity in order to investigate their relation to the state of presence of users in virtual reality.

6.3 Reflections

At the end of the study, I was satisfied with the project that I was able to present considering all the obstacles that hindered my progress. I started the setup in the university lab, but I had to scrap everything, and restart the setup at home which was a total disappointment for me. I also had some problems on a personal level, but I was able to overcome all the personal and technical problems that I faced in the implementation phase of the project. This taught me lots of life lessons in overcoming problems and working hard in order to find solutions to the problems that face me. In addition to that, this experience taught me a lot of important skills including statistical analysis, time management, planning, and problem solving. This was an experience that I will always cherish and appreciate.

Bibliography

Aldaba, C.N. and Moussavi, Z., 2020. Effects of virtual reality technology locomotive multi-sensory motion stimuli on a user simulator sickness and controller intuitiveness during a navigation task. *Medical & Biological Engineering & Computing*, *58*(1), pp.143-154.

Althaus, P., Ishiguro, H., Kanda, T., Miyashita, T. and Christensen, H.I., 2004, April. Navigation for human-robot interaction tasks. In *IEEE International Conference on Robotics and Automation, 2004. Proceedings. ICRA'04. 2004*(Vol. 2, pp. 1894-1900). IEEE.

Baños, R.M., Botella, C. and Perpiñá, C., 1999. Virtual reality and psychopathology. *CyberPsychology & Behavior*, *2*(4), pp.283-292.

Barfield, W. and Weghorst, S., 1993. The sense of presence within virtual environments: A conceptual framework. *Advances in Human Factors Ergonomics*, *19*, pp.699-699.

Biocca, F. and Delaney, B., 1995. Immersive virtual reality technology. *Communication in the age of virtual reality*, *15*, p.32.

Biocca, F., 1997. The cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of computer-mediated communication*, *3*(2), p.JCMC324.

Boon, S.D. and Lomore, C.D., 2001. Admirer-celebrity relationships among young adults: Explaining perceptions of celebrity influence on identity. *Human communication research*, *27*(3), pp.432-465.

Borst, K.J., Boyd, J. and Kwant, M., Ganz, 2014. *Method and system for providing a virtual presentation including a virtual companion and virtual photography*. U.S. Patent 8,795,072.

Brown, E. and Cairns, P., 2004, April. A grounded investigation of game immersion. In *CHI'04 extended abstracts on Human factors in computing systems* (pp. 1297-1300).

Byagowi, A., Mohaddes, D. and Moussavi, Z., 2014. Design and application of a novel virtual reality navigational technology (VRNChair). *Journal of experimental neuroscience*, *8*, pp.JEN-S13448.

Carnegie, K. and Rhee, T., 2015. Reducing visual discomfort with HMDs using dynamic depth of field. *IEEE computer graphics and applications*, *35*(5), pp.34-41.

Chen, G., Gully, S. M., & Eden, D. (2001). Validation of a new general self-efficacy scale. *Organizational Research Methods*, *4*(1), 62-83.

Cooper, N., Milella, F., Cant, I., Pinto, C., White, M. and Meyer, G., 2015. The effects of multisensory cues on the sense of presence and task performance in a virtual reality environment.

Davis, S., Nesbitt, K. and Nalivaiko, E., 2015, January. Comparing the onset of cybersickness using the Oculus Rift and two virtual roller coasters. In *Proceedings of the 11th Australasian Conference on Interactive Entertainment (IE 2015)* (Vol. 27, p. 30).

De Koven, B., 2013. *The well-played game: A player's philosophy*. mit Press.

Dennison, M.S., Wisti, A.Z. and D'Zmura, M., 2016. Use of physiological signals to predict cybersickness. *Displays*, *44*, pp.42-52.

Downs, E., Bowman, N. D., & Banks, J. (2019). A polythetic model of player-avatar identification: Synthesizing multiple mechanisms. *Psychology of Popular Media Culture*, *8*(3), 269.

Dowrick, P., 1983. Self-modeling. *Using video: Psychological and social applications*.

Draper, J.V., Kaber, D.B. and Usher, J.M., 1998. Telepresence. *Human factors*, *40*(3), pp.354-375.

Draper, J.V., Kaber, D.B. and Usher, J.M., 1998. Telepresence. *Human factors*, *40*(3), pp.354-375.

Ebenholtz, S.M., Cohen, M.M. and Linder, B.J., 1994. The possible role of nystagmus in motion sickness: a hypothesis. *Aviation, space, and environmental medicine*, *65*(11), pp.1032-1035.

Ergonomics Society Annual Meeting (Vol. 39, No. 21, pp. 1410-1414). Sage CA: Los Angeles, CA: SAGE Publications.

Gálvez-García, G., Hay, M. and Gabaude, C., 2015. Alleviating simulator sickness with galvanic cutaneous stimulation. *Human factors*, *57*(4), pp.649-657.

Gamito, P., Oliveira, J., Santos, P., Morais, D., Saraiva, T., Pombal, M. and Mota, B., 2008. Presence, immersion and cybersickness assessment through a test anxiety virtual environment. *Annual Review of CyberTherapy and Telemedicine*, *6*, pp.83-90.

Gavgani, A.M., Nesbitt, K.V., Blackmore, K.L. and Nalivaiko, E., 2017. Profiling subjective symptoms and autonomic changes associated with cybersickness. *Autonomic Neuroscience*, *203*, pp.41-50.

Harrell, D.F., 2012. Imagination and empowerment with video game characters. Game Developers Conference, March 5-9, San Francisco, CA.

Hoffner, C. and Buchanan, M., 2005. Young adults' wishful identification with television characters: The role of perceived similarity and character attributes. *Media psychology*, *7*(4), pp.325-351.

IJsselsteijn, W.A., 2005. Towards a neuropsychological basis of presence. *Annual Review of CyberTherapy and Telemedicine*, *3*, pp.25-30.

Iskander, J., Attia, M., Saleh, K., Abobakr, A., Nahavandi, D., Hossny, M., & Nahavandi, S. (2019, October). Exploring the Effect of Virtual Depth on Pupil Diameter. In *2019 IEEE International Conference on Systems, Man and Cybernetics (SMC)* (pp. 1849-1854). IEEE.

International Society for Presence Research, 2000. The concept of presence: Explication statement.

Jackson, S.A. and Csikszentmihalyi, M., 1999. *Flow in sports*. Human Kinetics.

John, B. (2019, June). Pupil diameter as a measure of emotion and sickness in VR. In *Proceedings of the 11th ACM Symposium on Eye Tracking Research & Applications* (pp. 1-3).

Jurnet, I.A., Beciu, C.C. and Maldonado, J.G., 2005. Individual differences in the sense of presence. In *Proceedings of Presence 2005: The 8th International Workshop on Presence*(pp. 133-142).

Kaul, O. B., Meier, K., & Rohs, M.,2017. Increasing presence in virtual reality with a vibrotactile grid around the head. In *IFIP Conference on Human-Computer Interaction* (pp. 289-298). Springer, Cham.

Keehner, M.M., Tendick, F., Meng, M.V., Anwar, H.P., Hegarty, M., Stoller, M.L. and Duh, Q.Y., 2004. Spatial ability, experience, and skill in laparoscopic surgery. *The American Journal of Surgery*, *188*(1), pp.71-75.

Kennedy, R.S., Lane, N.E., Berbaum, K.S. and Lilienthal, M.G., 1993. Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, *3*(3), pp.203-220.

Kennedy, R.S., Drexler, J. and Kennedy, R.C., 2010. Research in visually induced motion sickness. *Applied ergonomics*, *41*(4), pp.494-503.

Kinsella, A., 2014. The effect of 0.2 Hz and 1.0 Hz frequency and 100 ms and 20-100 ms amplitude of latency on simulatory sickness in a head mounted display.

Kyllonen, P.C. and Chaiken, S., 2003. Dynamic spatial ability and psychomotor performance. *International Journal of Testing*, *3*(3), pp.233-249.

Lang, D.J., 2016. For virtual reality creators, motion sickness a real issue.
Lee, J., Kim, M. and Kim, J., 2017. A study on immersion and VR sickness in walking interaction for immersive virtual reality applications. *Symmetry*, *9*(5), p.78.

Lewis, G.S., Valentino, J. and Bothwell, C.M., Textron Innovations Inc, 2015. *System and method for controlling a virtual reality environment by an actor in the virtual reality environment*. U.S. Patent 9,013,396.

Lin, C.J., Chen, H.J., Cheng, P.Y. and Sun, T.L., 2015. Effects of Displays on Visually Controlled Task Performance in Three-Dimensional Virtual Reality Environment. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *25*(5), pp.523-533.

Lin, Y., Zhang, W. J., & Watson, L. G. (2001). Framework of Human-Machine Interface Design. *Human Friendly Mechatronics*, 61.

Little, G., 1999. A manifesto for avatars. *Intertexts*, *3*(2), p.192

Lombard, M. and Ditton, T., 1997. At the heart of it all: The concept of presence. *Journal of computer-mediated communication*, *3*(2), p.JCMC321.

Loomer, J.B., 1992. The evolution of a more rigorous approach to benefit transfer: benefit function transfer. Water Resources 28, pp701-705.

McCauley, M.E. and Sharkey, T.J., 1992. Cybersickness: Perception of self-motion in virtual environments. *Presence: Teleoperators & Virtual Environments*, *1*(3), pp.311-318.

McDonald, D.G. and Kim, H., 2001. When I die, I feel small: Electronic game characters and the social self. *Journal of Broadcasting & Electronic Media*, *45*(2), pp.241-258.

Moss, J.D. and Muth, E.R., 2011. Characteristics of head-mounted displays and their effects on simulator sickness. *Human factors*, *53*(3), pp.308-319.

Meehan, M., Razzaque, S., Whitton, M.C. and Brooks, F.P., 2003, March. Effect of latency on presence in stressful virtual environments. In *IEEE Virtual Reality, 2003. Proceedings.* (pp. 141-148). IEEE.

Minsky, M., 1980. Telepresence.

Munafo, J., Diedrick, M. and Stoffregen, T.A., 2017. The virtual reality head-mounted display Oculus Rift induces motion sickness and is sexist in its effects. *Experimental brain research*, *235*(3), pp.889-901.

Myers, B., I. with Myers, P.(1980) Gifts Differing: Understanding personality type.

Nichols, S., Haldane, C. and Wilson, J.R., 2000. Measurement of presence and its consequences in virtual environments. *International Journal of Human-Computer Studies*, *52*(3), pp.471-491.

Paíga, P., Santos, L.H., Ramos, S., Jorge, S., Silva, J.G. and Delerue-Matos, C., 2016. Presence of pharmaceuticals in the Lis river (Portugal): Sources, fate and seasonal variation. *Science of the Total Environment*, *573*, pp.164-177.

Pierre, M.E.S., Banerjee, S., Hoover, A.W. and Muth, E.R., 2015. The effects of 0.2 Hz varying latency with 20–100 ms varying amplitude on simulator sickness in a helmet mounted display. *Displays*, *36*, pp.1-8.

Prothero, J.D., Hoffman, H.G., Parker, D.E., Furness III, T.A. and Wells, M.J., 1995, October. Foreground/background manipulations affect presence. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 39, No. 21, pp. 1410-1414). Sage CA: Los Angeles, CA: SAGE Publications.

Raney, A.A., 2004. Expanding disposition theory: Reconsidering character liking, moral evaluations, and enjoyment. *Communication theory*, *14*(4), pp.348-369.

Rebenitsch, L. and Owen, C., 2016. Review on cybersickness in applications and visual displays. *Virtual Reality*, *20*(2), pp.101-125.

Regan, C., 1995. An investigation into nausea and other side-effects of head-coupled immersive virtual reality. *Virtual Reality*, *1*(1), pp.17-31.

Resnick, B. and Jenkins, L.S., 2000. Testing the reliability and validity of the self-efficacy for exercise scale. *Nursing research*, *49*(3), pp.154-159.

Riccio, G.E. and Stoffregen, T.A., 1991. An ecological theory of motion sickness and postural instability. *Ecological psychology*, *3*(3), pp.195-240.

Riding, R.J., 1998. Cognitive styles analysis—research applications. *Birmingham Learning and Training Technology*.

Riva, G., Davide, F. and IJsselsteijn, W.A., 2003. Being there: The experience of presence in mediated environments. *Being there: Concepts, effects and measurement of user presence in synthetic environments*, *5*.

Sas, C. and O'Hare, G.M.P., 2003. Impact of cognitive style upon sense of presence. In *Proceedings of HCI International*(pp. 696-700).

Sas, C., O’Hare, G.M. and Reilly, R., 2004. Presence and task performance: an approach in the light of cognitive style. *Cognition, Technology & Work*, *6*(1), pp.53-56.

Schaik, P.V., Turnbull, T., Wersch, A.V. and Drummond, S., 2004. Presence within a mixed reality environment. *CyberPsychology & Behavior*, *7*(5), pp.540-552.

Schubert, T., Friedmann, F. and Regenbrecht, H., 2001. The experience of presence: Factor analytic insights. *Presence: Teleoperators & Virtual Environments*, *10*(3), pp.266-281.

Schuemie, M.J., Abel, B., van der Mast, C.A.P.G., Krijn, M. and Emmelkamp, P.M.G., 2005. The effect of locomotion technique on presence, fear and usability in a virtual environment. In *EUROMEDIA* (Vol. 2005, p. 11th).

Schwind, V., Knierim, P., Haas, N. and Henze, N., 2019, May. Using presence questionnaires in virtual reality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems* (pp. 1-12).

Sheridan, T.B., 1992. Musings on telepresence and virtual presence. *Presence: Teleoperators & Virtual Environments*, *1*(1), pp.120-126.

Skopp, N.A., Smolenski, D.J., Metzger-Abamukong, M.J., Rizzo, A.A. and Reger, G.M., 2014. A pilot study of the virtusphere as a virtual reality enhancement. *International Journal of Human-Computer Interaction*, *30*(1), pp.24-31.

Slater, M., Usoh M., 1993. Representational systems, perceptual position, and presence in virtual environments. *Presence: Teleoperators & Virtual Environments* 2, pp.221-233.

Slater, M., Usoh, M. and Steed, A., 1994. Depth of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *3*(2), pp.130-144.

Slater, M., McCarthy, J. and Maringelli, F., 1998. The influence of body movement on subjective presence in virtual environments. *Human Factors*, *40*(3), pp.469-477.

Slater, M., 2004. Presence and emotions. *Cyberpsychology & Behavior*, *7*(1), pp.121-121.

Smeulders, A.W., Chu, D.M., Cucchiara, R., Calderara, S., Dehghan, A. and Shah, M., 2013. Visual tracking: An experimental survey. *IEEE transactions on pattern analysis and machine intelligence*, *36*(7), pp.1442-1468.

Stanney, K. and Salvendy, G., 1998. Aftereffects and sense of presence in virtual environments: Formulation of a research and development agenda. *International Journal of Human-Computer Interaction*, *10*(2), pp.135-187.

Stanney, K.M. and Kennedy, R.S., 1997. The psychometrics of cybersickness. *Communications of the ACM*, *40*(8), pp.66-68.

Stern, J. A., Boyer, D., & Schroeder, D. (1994). Blink rate: a possible measure of fatigue. *Human factors*, *36*(2), 285-297.

Takatalo, J., Nyman, G. and Laaksonen, L., 2008. Components of human experience in virtual environments. *Computers in Human Behavior*, *24*(1), pp.1-15.

Thornson, C.A., Goldiez, B.F. and Le, H., 2009. Predicting presence: Constructing the tendency toward presence inventory. *International Journal of Human-Computer Studies*, *67*(1), pp.62-78.

Treisman, M., 1977. Motion sickness: an evolutionary hypothesis. *Science*, *197*(4302), pp.493-495.

Trepte, S., Reinecke, L. and Behr, K.M., 2009. Creating virtual alter egos or superheroines? Gamers' strategies of avatar creation in terms of gender and sex. *International Journal of Gaming and Computer-Mediated Simulations (IJGCMS)*, *1*(2), pp.52-76.

Usoh, M., Arthur, K., Whitton, M., Bastos, R., Steed, A., Brooks, F. and Slater, M., 1999, April. The visual cliff revisited: A virtual presence study on locomotion. In *Second International Workshop on Presence. University of Essex, Colchester*.

Walter, Hannah; Li, Ruixuan; Munafo, Justin; Curry, Christopher; Peterson, Nicolette; Stoffregen, Thomas. (2019). APAL Coupling Study 2019. Retrieved from the Data Repository for the University of Minnesota, https://doi.org/10.13020/XAMG-CS69.

Webster, J., Trevino, L.K. and Ryan, L., 1993. The dimensionality and correlates of flow in human-computer interactions. *Computers in human behavior*, *9*(4), pp.411-426.

Witmer, B.G. and Singer, M.J., 1998. Measuring presence in virtual environments: A presence questionnaire. *Presence*, *7*(3), pp.225-240.

Witmer, B.G., Jerome, C.J. and Singer, M.J., 2005. The factor structure of the presence questionnaire. *Presence: Teleoperators & Virtual Environments*, *14*(3), pp.298-31

Weech, S., Kenny, S. and Barnett-Cowan, M., 2019. Presence and cybersickness in virtual reality are negatively related: a review. *Frontiers in psychology*, *10*, p.158.

Youngblut, C. and Perrin, B.M., 2002. Investigating the relationship between presence and performance in virtual environments. *Paper presented at IMAGE 2002 Conference, Scottsdale,AZ.*

Zielasko, D., Horn, S., Freitag, S., Weyers, B. and Kuhlen, T.W., 2016, March. Evaluation of hands-free HMD-based navigation techniques for immersive data analysis. In *2016 IEEE Symposium on 3D User Interfaces (3DUI)* (pp. 113-119). IEEE.

Appendix A

Presence Questionnaire

Item Questions	Factors	Subscale	ITCorr
1-How much were you able to control events?	CF	INV/C	0.43*
2-How responsive was the environment to actions that you initiated (or performed)?	CF	INV/C	0.56*
3-How natural did your interactions with the environment seem?	CF	NATRL	0.61*
4-How completely were all of your senses engaged?	SF		0.39*
5-How much did the visual aspect of the environment involve you?	SF	INV/C	0.48*
6-How much did the auditory aspects of the environment involve you?	SF	AUD	0.32*
7-How natural was the mechanism which controlled movement through the environment?	CF	NATRL	0.62*
8-How aware were you of events occurring in the real world around you?	DF		0.03
9-How aware were you of your display and control devices?	DF		-0.14
10-How compelling was your sense of objects moving through space?	SF	INV/C	0.51*
11-How inconsistent or disconnected was the information coming from various senses?	RF		0.33*
12-How much did your experiences in the virtual environment seem consistent with your real-world experiences?	RF,CF	NATRL	0.62*
13-Were you able to anticipate what would happen next in response to the actions that you performed?	CF	INV/C	0.43*
14-How completely were you able to actively survey	RF,CF,SF	INV/C	0.59*

or search the environment using vision?			
15-How well could you identify sounds?	RF,SF	AUD	0.34*
16- How well could you localize sounds?	RF,SF	AUD	0.30*
17-How well could you actively survey or search the virtual environment using touch?	RF,SF	HAPTC	0.15
18-How compelling was your sense of moving around inside the virtual environment?	SF	INV/C	0.62*
19-How closely were you able to examine objects?	SF	RESOL	0.55*
20-How well could you examine objects from multiple viewpoints?	SF	RESOL	0.49*
21-How well could you move or manipulate objects in the virtual environment?	CF	HAPTC	0.11
22-To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?	RF		-0.06
23-How involved were you in the virtual experience?		INV/C	0.52*
24-How distracting was the control mechanism?	DF		0.37*
25-How much delay did you experience between your actions and expected outcomes?	CF	INV/C	0.41*
26-How quickly did you adjust to the virtual environment experience?	CF	INV/C	0.41*
27-How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	CF	INV/C	0.45*
28-How much did the visual display quality interfere or distract you from performing quests or activities?	DF	IFQUAL	0.44*
29-How much did the control devices interfere with the performance of assigned tasks or with other activities?	DF,CF	IFQUAL	0.44*
30-How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?	DF	IFQUAL	0.51*
31-Did you learn new techniques that enabled you to improve your performance?	CF		0.33*
32-Were you involved in the experimental task to the extent that you lost track of time?		INV/C	0.41*

Factors:
CF = Control Factors
SF=Sensory Factors
DF= Distraction Factors
RF= Realism Factors

Subscales:
INV/C = Involvement/Control
NAT= Natural
AUD = Auditory
HAPTC = Haptic
RES = Resolution
IFQUAL = Interface Quality

ITCorr = Pearson correlation coefficients between PQ item scores and PQ Total Score.

Appendix B

Immersive Tendency Questionnaire

Questions:	Subscale
1-How often do you play arcade or video games?	GAME-EXP
2-You can describe me as a gamer?	GAME-EXP
3-Do you ever become so involved in a video game that it is as if you are inside the game rather than using a controller and controlling a character	ACTINV
4-Do you ever become involved in movies that you are not aware of things that are happening around you?	PASINV
5- How good are you at blocking external distractions when are involved in something?	ACTINV
6-When doing activities, do you become so involved that you lose track of time?	ACTINV
7-Have you ever remained apprehensive or fearful long after an event that scared you?	PASINV
8-Do you usually become so involved in a daydream that you are not aware of things happening around you?	PASINV
9-I consider that I have a good sense of direction	SPATOR
10-After having driven somewhere once, I can find it pretty easily	SPATOR
11-I have a good hand-eye coordination	SPATOR
12-I am often described as a quiet person	INTR
13-I am usually uncomfortable meeting new people	INTR
14-I usually prefer to keep to myself,away from the scrutiny of others	INTR
15-I try to avoid being the center of attention	INTR
16-I enjoy spending time imagining possibilities	PASINV
17-I often played make-believe or role-playing games as a child	PASINV
18-As a child I tended to pull things apart in order to check if I could reconstruct them	CMM
19-I enjoy lots of hobbies related to making things such as carpentry,drawing,arts,crafts …etc	CMM
20-If I'm trying to find a place in an unfamiliar area, I prefer that someone draws me a map	CMM
21- Most people describe me as warm-compassionate and sympathetic	EMP
22-I believe that I am too tender-hearted and quick to forgive	EMP
23-Taking other people's point of view into account is a top priority for me	EMP
24-Making sure that everyone gets along in my circle of friends is one of my priorities	EMP

EMP=Empathy
CMM= Construct mental models
PASINV= Passive Cognitive Involvement/Absorption
INTR = Introversion
SPATOR = spatial orientation
ACTINV = Active involvement
GAMEEXP = level of gaming experience

Appendix C

SSQ Questionnaire

Weights for Symptoms

Symptoms	Nausea	Oculomotor	Disorientation
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eye strain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total*	[1]	[2]	[3]

Calculations in the simulator Sickness:
None = 0
Slight = 1
Moderate = 2
Severe = 3
Total is the sum by adding the symptoms scores. Omitted scores are zeroes

Score
Nausea = [1] x 9.54

Oculomotor = [2] x 7.58
Disorientation = [3] x 13.92
*Total Score = ([1] + [2]+[3])*3.74*

Appendix D

Ploythetic model of avatar identification

Items	Subscale	Initial	Final	CFA std.path coefficients
1- I physically resemble this avatar	Physical Similarity	.912	.919	.88
2- My appearance is similar to this avatar	Physical Similarity	.911	.926	.91
3- I don't look anything like this avatar	Physical Similarity	.909	.895	.91
4- This avatar has an appearance like mine	Physical Similarity	.900	.904	.90
5- This avatar shares many physical characteristics with me	Physical Similarity	.853	.892	.86
6- Sometimes I wish I could be more like this avatar	Wishful Identification	.892	.905	.77
7- The avatar is someone that I would like to emulate	Wishful Identification	.784	.875	.77
8- The avatar is the kind of person I would like to be myself	Wishful Identification	.782	.873	.85
9- I like this avatar	Liking	.822	.863	.66
10- I dislike this avatar	Liking	.778	.715	.63
11- I have positive feelings toward this avatar	Liking	.714	.739	.78
12- I feel like this avatar is	Liking	.670	.693	.80

interesting				

Subscale Liking Descriptives : PCA $\alpha = .77$ *, (M = 6.46, SD = .67) ; CFA* $\alpha = .80$*,*
(M = 6.45, SD = .675)
Subscale Wishful Identification Descriptives: PCA $\alpha = .89$*, (M = 4.48, SD = 1.67); CFA* $\alpha =.867$*,*
(M = 4.57, SD = 1.59)
Subscale Physical Similarity : PCA $\alpha = .94$*, (M= 2.55, SD = 1.59); CFA* $\alpha =.94$*,*
(M= 2.57, SD = 1.64)
PCA = principle components analysis
CFA = confirmatory factor analysis

Appendix E

VAK Learning Questionnaire

1-When operating on a new equipment for the first time I prefer to:
- a-Read the instructions
- b-Listen or ask for an explanation
- c-Have a go and learn by trial and error

2-When seeking travel directions I:
- a-look at a map
- b-ask for spoken directions
- c-follow my nose or maybe a compass

3-When cooking a new dish I:
- a-follow a recipe
- b-call a friend for explanation
- c-follow my instinct, tasting as I cook

4-Complaining about faulty goods I tend to:
- a-write a letter
- b-phone
- c-go back to the store, or send the faulty item to the head office

5-When shopping generally I tend to:
- a-look and decide
- b-discuss with shop staff
- c-try on, handle or test

6-Learning a new skill:
a-I watch what the teacher is doing
b-I talk through with the teacher exactly what I am supposed to do
c-I like to give it a try and work it out as I go along by doing it

7-I feel especially connected to others because of:
a-how they look
b-What they say to me
c-How they make me feel

8-Most of my free time is spent:
a-Watching television
b-Talking to friends
c-doing physical activity or making things

9-If I am very angry
a-I keep replaying in my mind what it is that has upset me
b-I shout lots and tell people how I feel
c-I stomp about, slam doors and throw things

10- When concentrating I:
a-focus on the words or pictures in front of me
b-discuss the problem and possible solutions in my head
c-move around a lot, fiddle with pens and pencils and touch unrelated things

a→ Visual
b→ Auditory
c→ kinesthetic/physical

Appendix F

University of Bath Health Screening Questionnaire

Health Screen Participant Number:

It is important that volunteers participating in research studies are currently in good health to exercise. This is to ensure (i) their own continued well-being and (ii) to avoid the possibility of introducing bias into the study outcomes.
Please complete this questionnaire to confirm your eligibility to participate

1. At present, do you have any health problem for which you are:
   a- On medication, prescribed or otherwise Yes No
   b- Attending your general practitioner Yes No

2. As far as you are aware, do you suffer, or have you ever suffered from:
   a- Convulsions/epilepsy Yes No
   b- Asthma Yes No
   c- Pressure sores Yes No
   d- Diabetes Yes No
   e- A blood disorder Yes No
   f- Head injury Yes No
   g- Digestive problems Yes No
   h- Heart problems Yes No
   i- Disturbance of balance/coordination Yes No
   j- Disturbance of vision Yes No
   k- Ear/hearing problems Yes No
   l- Thyroid problems Yes No
   m- Kidney or liver problems Yes No
   n- Urinary tract infection Yes No
   o- Cognitive impairment Yes No
   p- *Autonomic dysreflexia Yes No

3. Has any, otherwise healthy, member of their family under the age 35 died suddenly during or soon after exercise. Yes No

If YES to any question, please briefly describe if you wish (eg to confirm problem was/is short-lived, insignificant or well controlled.)

……………………………………………………………………………………………
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Note: Questions indicated by (*) requires your doctor to fill out the 'Doctors Consent Form'

Signature: ………………………………………..

Date: ………………………………………………..

Thank you for your cooperation!

Appendix G

Participant Consent Form

Participant Consent Form

☐ The nature, aims and risks of the research have been explained to me

☐ I have read and understood the Participant Instruction Sheet.

☐ I understand what is expected of me.

☐ I understand that I can withdraw from the study at any time without giving a reason.

☐ Any questions I have about my participation in this study have been answered satisfactorily.

☐ I am taking part in this study voluntarily.

☐ I consent to the processing of my personal information for the purpose of this research study.

☐ I am willing to be video recorded whilst taking part in this.

☐ I understand that my identity will not be linked to any data retrieved in this study.

☐ I understand that my information will be treated strictly confidential in accordance with the Data Protection Act 1998.

☐ I feel well enough to participate in the study.

☐ I am aware of the potential risks of using virtual reality headgear, whilst physically exerting myself.

☐ I agree not to talk about the design of the experiment to others until data from all the participants has been collected.

☐ I agree to volunteer as a subject for the study described in the information sheet and I give full consent to my participation in this study.

I, the participant, consent to all points made above:

Signature:

Date:

I, the study conductor, promise to protect the confidentiality of the participant, and will only use the data collected in this study for research purposes:

Signature:

Date:

Appendix H

12 Point Ethics Checklist

Does your project involve people for the collection of data other than you and your supervisor(s)?
YES / NO

If the answer to the previous question is YES, you need to answer the following questions, otherwise you can ignore them.

This document describes the 12 issues that need to be considered carefully before students or staff involve other people ('participants' or 'volunteers') for the collection of information as part of their project or research. Replace the text beneath each question with a statement of how you address the issue in your project.

1. *Have you prepared a briefing script for volunteers?*
YES / NO
Briefing means telling someone enough in advance so that they can understand what is involved and why – it is what makes informed consent informed.

2. *Will the participants be informed that they could withdraw at any time?*
YES / NO
All participants have the right to withdraw at any time during the investigation, and to withdraw their data up to the point at which it is anonymised. They should be told this in the briefing script.

3. *Is there any intentional deception of the participants?*
YES / NO

Withholding information or misleading participants is unacceptable if participants are likely to object or show unease when debriefed.

4. *Will participants be de-briefed?*
YES / NO
The investigator must provide the participants with sufficient information in the debriefing to enable them to understand the nature of the investigation. This phase might wait until after the study is completed where this is necessary to protect the integrity of the study.

5. *Will participants voluntarily give informed consent?*
YES / NO
Participants MUST consent before taking part in the study, informed by the briefing sheet. Participants should give their consent explicitly and in a form that is persistent –e.g. signing a form or sending an email. Signed consent forms should be kept by the supervisor after the study is complete.

6. *Will the participants be exposed to any risks greater than those encountered in their normal work life (e.g., through the use of non-standard equipment)?*
YES / NO
Investigators have a responsibility to protect participants from physical and mental harm during the investigation. The risk of harm must be no greater than in ordinary life.

7. *Are you offering any incentive to the participants?*
YES / NO
The payment of participants must not be used to induce them to risk harm beyond that which they risk without payment in their normal lifestyle.

8. *Are you in a position of authority or influence over any of your participants?*
YES / NO
A position of authority or influence over any participant must not be allowed to pressurise participants to take part in, or remain in, any experiment.

9. *Are any of your participants under the age of 16?*

YES / NO

Parental consent is required for participants under the age of 16.

10. *Do any of your participants have an impairment that will limit Their understanding or communication?*

YES / NO

Additional consent is required for participants with impairments.

11. *Will the participants be informed of your contact details?*

YES / NO

All participants must be able to contact the investigator after the investigation. They should be given the details of the Supervisor as part of the debriefing.

12. *Do you have a data management plan for all recorded data?*

YES / NO

All participant data (hard copy and soft copy) should be stored securely, and in anonymous form, on university servers (not the cloud). If the study is part of a larger study, there should be a data management plan.

Appendix I

Self- Perception Questionnaire

1-I will be able to achieve most of the goals that I have set for myself.
2-When facing difficult tasks, I am certain that I will accomplish them.
3-In general, I think that I can obtain outcomes that are important to me.
4-I believe I can succeed at almost any endeavour to which I set my mind.
5-I will be able to successfully overcome many challenges.
6-I am confident that I can perform effectively on many different tasks.
7-Compared to other people, I can do most tasks very well.
8-Even when things are tough, I can perform quite well.
9-I consider myself an active person who exercises a lot.
10-I believe that physical activity is important to me and it will benefit me on many different levels.

Appendix J

DATA

The data will be attached with the dissertation.