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ACHIEVING THE EXPERIENCE OF IMMERSION IN VIRTUAL REALITY

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ABSTRACT

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The VR industry is growing. Despite modern VR technologies being primarily marketed for entertainment purposes, VR has also been used in numerous professional settings and is expected to be adopted into countless others as the technology becomes more widespread. Therefore, researching ways to provide the best possible experience for its users is becoming more and more important.

As the experience of immersion has been stated as a key component of the enjoyment of interactive media experiences, this thesis set out to answer the research question of how the experience of immersion is achieved with modern VR technologies.

The literature review presented a conceptual model of the experience of immersion for extended reality technologies, which suggested that the experience of immersion consists of three dimensions: physical presence (PP), social/self presence (SP), and involvement (INV). These dimensions are influenced by the technology, the content, and subjective factors. As this model had not been previously examined, the empirical study conducted in this thesis took the first step in examining this model.

The empirical study was done as an online structured survey during the spring of 2021. The study was targeted towards VR set owners with moderate to high levels of experience (N=347). Likely due to problems with the questionnaire, the full model could not be examined. However, examination into a partial model showed interesting results that future studies examining the model should consider.

Examination of the partial model showed that PP, SP, and INV explained 41,9% of the variance in the experience of immersion.

Keywords: virtual reality, immersion, presence, involvement, human-computer interaction

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VR-ala on kasvamassa. Vaikka modernia VR teknologiaa mainostetaan erityisesti viihdekäyttöön, VR:ää on käytetty lukuisissa ammateissa, ja uskotaan, että VR teknologia tullaan ottamaan käyttöön useissa muissa, kun teknologia yleistyy. Siten, on yhä tärkeämpää tutkia tapoja, joilla sen käyttökokemusta voidaan parantaa.

Immersion kokemuksen on kerrottu olevan keskeinen komponentti interaktiivisten mediakokemusten nautinnollisuudessa, joten tämä tutkielma lähti vastaamaan tutkimuskysymykseen, kuinka immersion kokemus saavutetaan moderneilla VR teknologioilla.

Kirjallisuuskatsaus esitti käsitteellisen mallin immersion kokemuksesta XR (extended reality) teknologioilla. Tämä malli esitti, että immersion kokemus koostuu kolmesta dimensiosta: fyysinen läsnäolo (physical presence, PP), sosiaalinen/itse läsnäolo (social/self presence, SP), ja osallisuus (involvement, INV). Näihin dimensioihin vaikuttavat teknologia, sisältö (content), ja subjektiiviset tekijät. Koska tätä mallia ei ollut empiirisesti tutkittu, tässä tutkielmassa suoritettu empiirinen tutkimus pyrki ottamaan ensimmäisen askeleen sen empiiriseen tutkimiseen.

Tutkielman empiirinen tutkimusosuus suoritettiin strukturoidulla kyselytutkimuksella kevään 2021 aikana. Aineisto kerättiin VR settien omistajilta, joilla oli keskinkertaisesti tai paljon kokemusta VR:n käytöstä (N=347). Kuitenkin todennäköisesti kyselylomakkeesta johtuvien ongelmien vuoksi, täyttä mallia ei pystytty testaamaan. Osittaisen mallin tarkastelu kuitenkin löysi mielenkiintoisia tuloksia, jotka mallin tulevissa tutkimuksissa tulisi ottaa huomioon.

Osittaisen mallin tarkastelu näytti, että PP, SP, ja INV selittivät 41,9 % immersion kokemuksen varianssista.

Asiasanat: virtuaalitodellisuus, immersio, läsnäolo, osallisuus, ihmisen ja tietokoneen välinen vuorovaikutus

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1 INTRODUCTION

During the past 50 years, virtual reality (VR) technology has been represented in media as a futuristic technology, which allows people to be submerged into amazing (or terrifying) virtual worlds and transcend the limitations of our physical world. Notable examples of these include the Holodeck from Star Trek: The Next Generation (1987), The Matrix from the Matrix series (1999), and more recently, the VR entertainment universe OASIS from Ernest Cline's novel Ready Player One (2011). However, this type of technology is not as far from reality as one might assume.

Although it may seem that VR technology has only started popping up during the past 5 years, it might surprise some that the concept of what is considered modern VR has existed for over 50 years (Cummings & Bailenson, 2016; Sutherland, 1965). Ivan Sutherland first proposed the concept for a device that could be considered the grandfather of modern head-mounted displays (HMDs) in 1965, which was then realized a few years later in 1968. This device was dubbed the "Sword of Damocles" (Sutherland, 1968; Slater & Sanchez-Vives, 2016; Pausch, Proffitt & Williams, 1997).

The concept of simulating a user's sensory environment did not gain the term "virtual reality" until around 30 years ago when VR reemerged during the late 1980s and 1990s due to advancements in technology (Slater & Sanchez-Vives, 2016; Weech, Kenny & Barnett-Cowan, 2019). This time VR reached the attention of the general public, which generated significant interest, speculation, and excitement for the potential of the technology (Slater & Sanchez-Vives, 2016). Even then, the technology was hailed as the beginning of a new era. However, the promises of mass availability and fidelity that generated this excitement quickly died down as the technology was expensive and the fidelity did not live up to the expectations. This caused VR to disappear from the public eye (Slater & Sanchez-Vives, 2016).

Thanks to the Oculus Rift (Oculus) released in 2016 and the many commercially available VR sets that followed it, the VR industry is experiencing a revival (Boletsis, 2017; Pallavicini, Pepe & Minissi, 2019; Volante et al., 2018). Advancements in technology have made VR devices more powerful, less cumbersome, and less expensive, which has led to them slowly starting to diffuse into the market (Angelov, Petkov, Shipkovenski & Kalushkov, 2020; Lee, 2021; Mütterlein, 2018). It seems that VR is finally starting to live up to the promises and potential which was suggested all those years ago (Slater & Sanchez-Vives, 2016), and resemble the technology that has been portrayed as sci-fi for so many years.

While modern VR technologies are commonly marketed as a new way to experience media or entertainment, VR technology has various and significant uses outside the entertainment field (Slater & Sanchez-Vives, 2016). VR technology has been used in numerous professional fields, such as medicine, psychology, psychotherapy, and military, and is expected to be adopted into countless others (Bowman & McMahan, 2007; Slater & Sanchez-Vives, 2016; Pallavicini et al., 2019; Mehrfard et al., 2019). Furthermore, the increased availability of VR devices for business and research settings will inevitably lead to even more use cases for the technology in the future (Slater & Sanchez-Vives, 2016). VR has been stated to have the potential to have a significant impact to society (Slater & Sanchez-Vives, 2016).

As mentioned earlier, VR technologies allow users to be submerged in alternate worlds. This concept of "submersion" hints at an important concept related to VR, that is immersion. After all, VR technologies are often referred to as immersive technologies (e.g., Lee, 2021). However, what this exactly means is often left unspecified (Brown & Cairns, 2004; Ermi & Mäyrä, 2005). Immersion has been defined in various ways to mean various things depending on the context (e.g., Agrawal, Simon, Bech & Bærentsen, 2020; Lee, 2021). Despite this, it is generally understood that it relates to being surrounded by or submerged in something (e.g., Ermi & Mäyrä, 2005; Murray, 1997; Nilsson, Nordahl & Serafin, 2016). When talking about VR, immersion commonly refers to being surrounded by the technology (Nilsson et al., 2016). However, an alternative way to view immersion is that it refers to the subjective experience of being surrounded or submerged (Nilsson et al., 2016). This view of immersion has been widely explored in many different fields, but most notably digital games (e.g., Nilsson et al., 2016). In this context, immersion refers to a highly sought-after subjective experience during which the user "loses" themselves in the game and feels as though they are "in the game" (Jennett et al., 2008). This experience has been viewed as a central aspect to the enjoyment of games and interactive media (e.g., Hudson, Matson-Barkat, Pallamin & Jegou, 2018; Jennett et al., 2008), and this is the experience that this thesis focuses on examining.

The purpose of this thesis is to examine the current research on the concept of immersion, what it means and how it is used in the context of VR. This thesis attempts to explain how the experience of immersion is achieved with VR sets and what factors of modern VR technologies influence it. Therefore, the research question is:

- How is immersion achieved with modern virtual reality technologies?

Examining this question started by conducting a literature review of the theoretical background. The articles were found using Google Scholar with search terms related to “virtual reality”, “VR”, “VR technologies”, “immersion”, “presence”, “social presence”, “self presence”, “involvement” and various combinations of these. Furthermore, a large portion of the articles were found by being referenced by other articles. The articles chosen for this thesis were chosen based on relevance to the research question, year they were published, as well as prominence, which was determined by the number of citations on Google Scholar. However, the number of citations for several articles are relatively low due to them being recently published. The year of publishing was chosen as an important criterion due to the significant technological advancements made in the VR industry over the past decade (Dużmańska, Strojny & Strojny, 2018).

Researching this topic is important and relevant for several reasons. First and foremost, it is commonly understood that the higher level of immersion a user feels, the more satisfying and enjoyable the experience is, both in the context of video games (e.g., Ermi & Mäyrä, 2005) as well as VR applications (Hudson et al., 2018; Pallavicini et al., 2019). Understanding how immersion is achieved with VR technologies can help VR hardware engineers and software developers to focus on aspects that positively influences the experience of immersion, or alternatively avoid or attempt to alleviate factors that negatively influence it.

However, this statement refers to immersion as a subjective experience. While immersion as a term is commonly used in the context of VR research (Lee, 2021), the VR field more commonly uses a definition of immersion that defines it as an objective property of the technology. According to this definition, the fidelity of the technology is tied to the level of immersion it provides (Slater, 2003). This difference in definitions highlights a second reason for the importance of examining this topic. Studies have only recently started to examine the experience of immersion in the context of VR (e.g., Mütterlein, 2018; Lee, 2021). Furthermore, in VR research, the concept of presence has been defined and used similarly to the concept of immersion as an experience (Cummings & Bailenson, 2016). Presence is commonly understood as a subjective experience during which a user feels a sense of “being” in a VE (e.g., Cairns, Cox & Nordin, 2014; Lee, 2021). Examining the experience of immersion in the context of VR, as well as the relationship between it and presence would assist in bridging the gap between VR research and other fields of study that have examined the experience of immersion more thoroughly.

Finally, to understand how the experience of immersion is achieved with modern VR technologies, examining the factors that influence it is also significant. This would help developers of VR applications and engineers of VR hardware to better understand how immersion is achieved and utilize this knowledge to improve future VR experiences and hardware. In addition, it would allow researchers to further examine the effects of these factors on the experience of immersion with modern VR technologies. Furthermore, these factors could assist private consumers and businesses on what to look for in a VR set when adopting VR technologies.

While empirically examining these factors influencing the experience of immersion from prior research is important, the scope of the thesis as well as concerns about the current COVID-19 pandemic would not allow for their examination. Instead, the empirical study conducted in this thesis focuses on examining a conceptual model of the experience of immersion presented by Lee (2021). This is significant as Lee's (2021) model is new and has not yet been empirically examined. Empirically examining this model is an important first step in empirically examining the experience of immersion with VR technologies, as the model was specifically created with extended reality (XR) technologies in mind (which includes VR), and it suggests clear relationships between the concepts of presence and the experience of immersion. Furthermore, this model could allow future researchers to examine how different factors influence the experience of immersion and its dimensions more closely.

Then, the empirical study of this thesis was conducted as a quantitative study using an online survey during the spring of 2021. In total, the survey received 683 responses, out of which 347 responses were included in the data analysis. The quantitative study sought to take the first step towards empirically examining the conceptual model on the experience of immersion in the context of VR proposed by Lee (2021). However, the full model Lee (2021) proposed was found problematic with this dataset, likely due to problems regarding the questionnaire and its limitations. Nevertheless, examining the problems the full model presented as well as examining a partial model yielded a number of interesting insights and notes that future studies examining the model should take note of. This means that this study adds to the recent trend of research on the relationship between presence and the experience of immersion, as well as the body of research on modern VR technologies.

The structure of the thesis is as follows. To provide context on modern VR technologies, the second chapter defines VR and presents a brief look at its quiet history, leading up to its current state, and its potential impact on society in the future. In addition, it presents several important concepts related to modern VR technologies as well as their most relevant components. The third chapter examines the concept of immersion. First, it presents two of the most relevant views on immersion that are relevant to the topic of this thesis: immersion as an objective property of the system and immersion as a subjective experience as well as how they relate to each other. Then, two concepts closely related to immersion are presented: presence and involvement, and their relationship with immersion is explored. The fourth chapter examines the role of immersion in the context of VR. This is done by summarizing the role of immersion as an experience in VR research, and presenting the conceptual model proposed by Lee (2021). In addition, it explores prior literature and presents four categories of factors that have been stated to influence the experience of immersion according to Lee's (2021) model, which are then related to its dimensions. Finally, it presents the hypotheses that will be examined in the empirical study. The fifth chapter introduces the empirical study done in this thesis and details how it was conducted. The sixth chapter presents the data analysis and briefly presents the results of the quantitative study. The seventh chapter summarizes the findings of the study and discusses its results. Additionally, it presents the limitations of the study and topics for future research. Finally, the eighth chapter is the conclusions which gives an overview of the thesis, what was found, and presents the implications of the results for research and practice.

2 VIRTUAL REALITY

This chapter introduces the concept of virtual reality (VR) and gives brief background on the history of the technology and its current state. Then, it presents the most important concepts and components of modern VR sets. In addition, it examines some suggested uses it may have in the future and its potential impact on society at large. Finally, one of the most notable issues related to VR, cyber sickness, is explained.

2.1 Defining VR and brief history of the technology

Virtual reality (VR) can be defined in several ways (Pallavicini et al., 2019). In the past, VR has been defined as a technology (Angelov et al., 2020), an application, or as an experience (Pallavicini et al., 2019). In this thesis, a definition of VR proposed by Biocca and Delaney (1995) is followed. The authors defined VR as: "the sum of the hardware and software systems that seek to perfect an all-inclusive, immersive, sensory illusion of being present in another environment" (Biocca & Delaney, 1995, p. 63).

The VR industry has seen significant advancements over the past decade, thanks to advancements in technology (Lee, 2021) as well as the significant reduction in production cost (Angelov et al., 2020). This increased availability and fidelity has led to a rapid increase in interest for the technology for consumers, researchers, and business enterprises alike (Angelov et al., 2020; Mütterlein & Hess, 2017; Pallavicini et al., 2019). Pallavicini et al. (2019) stated in their article that VR technology has enormous potential in various fields due to its ability to engage users more deeply than most traditional mediums. Since the reveal of the Oculus Rift (Oculus) in 2013 and its subsequent release in 2016, as well as the many commercially available VR sets that followed it, public interest for VR has seen a significant increase (Pallavicini et al., 2019). Boletsis (2017) called this revival of VR the "new era of Virtual Reality".

VR belongs under the umbrella term extended reality (XR) (Lee, 2021). The term XR covers the concepts of VR, augmented reality (AR), and mixed reality (MR) (Lee, 2021). These concepts cover the Reality-Virtuality Continuum (Figure 1) (Milgram & Kishino, 1994), which portrays how much of the real world is complemented by these technologies (Angelov et al., 2020). VR, as the name suggests, allows the user to be fully isolated from the physical environment by a head-mounted display (HMD) and only perceive the VE (rightmost side of the continuum) (Lee, 2021). Alternatively, AR allows the user to see the physical environment, and a wearable device akin to glasses superimposes virtual objects into it (Lee, 2021). MR devices, then, blends both experiences (Angelov et al., 2020). According to the continuum, VR provides the highest degree of virtuality, and therefore, can provide the highest level of immersion compared to AR and MR (Angelov et al., 2020). This thesis focuses on VR technologies because of the high level of immersion they can provide.

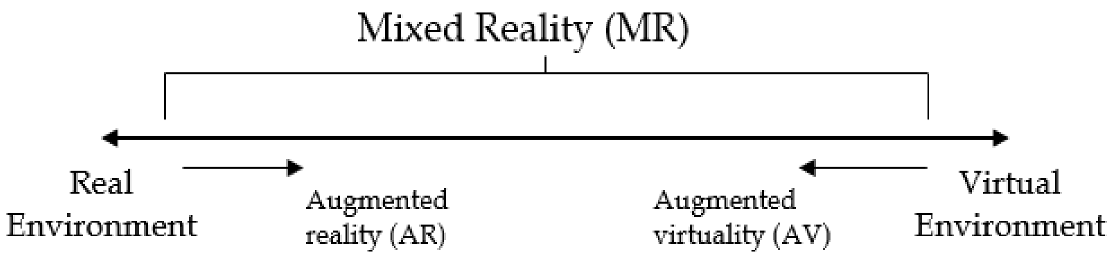

FIGURE 1: Reality-Virtuality Continuum (Milgram & Kishino, 1994, p. 3)

As mentioned in the introduction (Chapter 1), the idea behind VR technology, meaning an HMD and the ability to track the user's movements, is not new (Slater & Sanchez-Vives, 2016; Weech et al., 2019). The original concept was first introduced by Sutherland in 1965 (Sutherland, 1965), who then created the first HMD "Sword of Damocles" in 1968 (Sutherland, 1968; Slater & Sanchez-Vives, 2016; Pausch et al., 1997). However, the technologies it utilized were vastly different from modern VR sets (Slater & Sanchez-Vives, 2016). For example, the display of the "Sword of Damocles" depicted objects only as wireframes (Weech et al., 2019).

Despite the disappearance of VR from the public eye in the 1990s, VR technologies have been quietly developed in research environments and have seen applications in various fields, such as medicine, psychotherapy, neurosurgery, and military (Slater & Sanchez-Vives, 2016; Pallavicini et al., 2019; Mehrfard et al., 2019). However, as HMDs were impractical to produce due to technical limitations and high production costs (Mehrfard et al., 2019), alternate forms of VR were developed (Slater & Sanchez-Vives, 2016). One such system is the Cave, proposed by Cruz-Neira et al. (1992). The Cave system utilized projectors and shutter glasses to produce a 3D stereo image to the walls, floor, and ceiling of a small room (Cruz-Neira et al., 1992; Slater & Sanchez-Vives, 2016).

Since then, Cave systems were one of the primary means of conducting VR research until recently (Slater & Sanchez-Vives, 2016).

VR technology is extremely promising (Angelov et al., 2020), and Mütterlein (2018) proposed that VR might have the disruptive potential to change how media is consumed. However, Slater and Sanchez-Vives (2016) referenced Pausch et al. (1997), who stated that VR is still in a transitional stage. Even over 20 years later, this is still the case. Much like how movies used to borrow conventions from theater, the VR industry still uses a lot of conventions from other mediums, notably video games (Slater & Sanchez-Vives, 2016). Slater and Sanchez-Vives (2016) theorized that there will be a paradigm shift, which will completely redefine the conventions for VR, and significantly alter how VR applications are developed and utilized (Slater & Sanchez-Vives, 2016). However, what changes this will entail for the VR industry and society at large remain unknown until it happens (Slater & Sanchez-Vives, 2016).

It should be noted that while most of the cited studies are fairly recent and when talking about VR sets, have modern technical specifications in mind. However, some of the less recent studies could be talking about less technologically advanced VR sets.

2.2 Modern VR technologies

VR is rapidly growing in popularity (Volante et al., 2018). Boletsis (2017) states that the reveal of the Oculus Rift (Oculus) in 2013 was a milestone for the VR industry, because it rekindled the interest of the public and made VR a relevant topic again (Boletsis, 2017; Boletsis & Cedergren, 2019; Volante et al., 2018). All that excitement and potential that VR promised 30 years ago resurfaced, and the technology can finally live up to the expectations it set (Slater & Sanchez-Vives, 2016). The improvements in technology have permitted the simulation of expansive and immersive VEs with high quality graphics (Morie, 2006; Weech et al., 2019) and HMDs and computers have gotten more powerful and their displays more detailed (Angelov et al., 2020). HMDs have also gotten lighter, more comfortable, reliable, and easier to use (Morie, 2006). Furthermore, VR is finally seeing the wider adoption promised in the late 1980s as the prices have reduced (Martel & Muldner, 2017; Slater & Sanchez-Vives, 2016; Mütterlein & Hess, 2017).

2.2.1 HMDs

Head-mounted displays (HMDs) are the main component of VR sets. HMDs are wearable devices that a user wears on their head (e.g., Lee, 2021). By wearing an HMD, the user's vision is fully isolated from the physical environment and they are surrounded by the VE (Lee, 2021; Cho et al., 2017). In this thesis, the term VE is reserved to mean the virtual world displayed by the HMD.

Angelov et al. (2020) presented in their article the two classifications of modern VR HMDs: standalone and tethered (Angelov et al., 2020). Standalone HMDs are HMDs that do not need any external computing hardware. Standalone HMDs have a built-in computer that generates the VE they display. They also contain embedded sensors that track the position of the HMD to change the user's perspective according to their head movements. Due to not needing external devices, standalone devices have several benefits, such as increased mobility and comfort (Angelov et al., 2020). However, standalone HMD's also have several drawbacks, such as limited computing power due to their small size and limited time of use due to internal batteries (Angelov et al., 2020). Alternatively, tethered HMDs are required to be connected to a computer because they do not contain any computing hardware. The computing is done by the computer they are connected to. This allows for greater performance and virtually unlimited time of use. However, the disadvantage of tethered HMDs is the fact that they need to be connected to a computer via a cable, which reduces user comfort (Angelov et al., 2020). Angelov et al. (2020) stated that tethered HMDs provide the highest-quality VR experience available, and the authors attribute this to be the reason why tethered devices dominate the current VR hardware market (Angelov et al., 2020).

In addition, Angelov et al. (2020) briefly discussed two additional classifications of modern HMDs: mobile VR devices and hybrid HMDs. Mobile VR devices are HMDs that utilize the users' smartphone as its main component. An example of a mobile VR device is Google's Cardboard (Google), which is an HMD made of cardboard, and the user slots their mobile phone to act as the screen (Google; Angelov et al., 2020). Mobile VR devices function virtually the same as standalone HMDs and have the same advantages and disadvantages (Angelov et al., 2020). However, mobile VR devices do not provide any means of interacting with the virtual environment, such as hand-tracking or controllers (Angelov et al., 2020). Mobile VR devices are relatively cheap compared to the other classifications of HMDs mentioned, considering that they utilize the user's own smartphone (Angelov et al., 2020). Hybrid HMDs, such as Oculus Quest 2 (Oculus), are a newer addition to the VR hardware market (Oculus). They are HMDs that have the option to either utilize their internal hardware to function as a standalone HMD, or they can be connected to an external computer and used as a tethered HMD, which alleviates some of the problems of the standalone HMDs (Angelov et al., 2020).

2.2.2 Displays

Angelov et al. (2020) stated that displays are one of the most important components of HMDs since the user's perception of the VE depends on the quality of the HMDs display. This is also emphasized by Cho et al. (2017), who stated that the display technology is critical to VR since it is related to our vision. The display optics of HMDs consist of two primary components: the display(s) and lenses (Cho et al., 2017; Pallavicini et al., 2019). Most HMDs have two separate screens and two lenses, one of each for each eye (Slater & Sanchez-Vives, 2016). These screens display a 2D image of the VE at slightly different perspectives (Slater & Sanchez-Vives, 2016). This provides the user a 3D stereoscopic view of the VE, which has been reported to improve task efficiency and improved sense of presence (Bowman & McMahan, 2007; Weech et al., 2019). The images on the displays are projected through lenses, which magnify the images to cover most of the user's vision (Cho et al., 2017). Angelov et al. (2020) as well as Cho et al. (2017) emphasized the importance of the resolution of the displays and especially pixel density due to screen-door effect (SDE). SDE is caused by the magnification of the display image, which reduces the pixel density and makes the pixel matrix visible, which disturbs the user's immersion into the VE (Angelov et al., 2020; Cho et al., 2017).

Angelov et al. (2020) also emphasized two additional aspects of the displays that play a significant role in the user experience of HMDs: field-of-view (FoV) and refresh rate. The FoV determines the viewing angle of the user (Angelov et al., 2020). The average FoV of a human is up to 190°, and the closer the HMD can get to that value, the more natural the image appears (Angelov et al., 2020; Martel & Muldner, 2017). Angelov et al. (2020) state that for reaching a sense of presence, FoV has a more significant role than visual quality. This was also stated by Cummings and Bailenson (2016), who found empirical evidence from prior studies indicating that FoV provided a significantly stronger effect on presence than other factors, for example image quality. Refresh rate is the speed at which the virtual environment is rendered (Cummings & Bailenson, 2016). Angelov et al. (2020) suggest that HMDs should keep a refresh rate of at least 75hz to avoid negatively impacting the user experience.

To provide an overview of the technical specifications of typical modern HMDs, Angelov et al. (2020) presented technical specifications for the displays of five common commercially available tethered HMDs, which are the Oculus Rift S (Oculus), HTC Vive Pro (HTC), HTC Vive Cosmos (HTC), Valve Index (Valve), and Samsung HMD Odyssey+ (Samsung) (Angelov et al., 2020). Their resolution varies between 1280x1440 pixels to 1440x1600 pixels for each of the two screens, field of view between 90 degrees and 130 degrees, and refresh rate between 80hz and 144hz (Angelov et al., 2020). To give perspective on the technological advancements since the inception of HMDs, the "Sword of Damocles" had a refresh rate of 30hz and its FoV was 40 degrees, and these specifications were termed favorable by users (Sutherland, 1968; Weech et al., 2019).

2.2.3 Tracking

Tracking refers to the process of tracking the position or movement of the tracked device (Angelov et al., 2020). Angelov et al. (2020) stated that tracking is a key component of modern VR sets. The importance of tracking was also highlighted by Pal, Khan, and McMahan (2016), as well as Cummings and Bailenson

(2016), who stated that tracking level, meaning the amount of degrees of freedom (DOF) provided, and its veracity, has a significant positive effect on the sense of presence experienced.

Pal et al. (2016) presented three types of head tracking in their article: rotational 3-DOF, translational 3-DOF, and positional 6-DOF. DOF refers to degrees of freedom (DOF) each type of tracking provides (Pal et al., 2016). Rotational head tracking means tracking the rotation of the HMD, which allows the perspective of the user to change as they turn their head (Pal et al., 2016). This allows the user to have a 360° field-of-regard (FOR), meaning that they can freely look around in the VE (Pal et al., 2016). Translational head tracking refers to tracking the position of the user's head, meaning that the user can change their position, which in turn changes their viewpoint (Pal et al., 2016). Translational tracking provides the user with motion parallax cues, meaning depth cues from looking at objects from different angles (Narayan et al., 2005; Cummings & Bailenson, 2016; Pal et al., 2016). Complete 6-DOF (positional) tracking is most commonly used in modern VR sets and has been found to provide the best user experience out of the three types of tracking (Angelov et al., 2020; Pal et al., 2016; Cummings & Bailenson, 2016). In addition, the tracking types presented here apply for tracking controllers or other body parts of the user as well.

The methods modern VR sets use for tracking can be divided into two categories: outside-in and inside-out (Angelov et al., 2020). Outside-in tracking utilizes external cameras that track the position and movement of the tracked devices. In an inside-out system, the cameras are located directly on the tracked device itself, and they utilize markers (marker-based) or cues from the environment (markerless) to track their position (Angelov et al., 2020). Advantage of the inside-out method for tracking is the practicality that comes with the lack of external tracking hardware (Angelov et al., 2020). However, depending on the tracking method applied, the input veracity of the system can vary (Angelov et al., 2020; McMahan, Lai & Pal, 2016). McMahan et al., (2016) defined input veracity as "the objective degree of exactness with which the input devices capture and measure the user's actions" (McMahan et al., 2016). The authors further divide input veracity into three components: accuracy, meaning the exactness of the tracking; precision, meaning consistency of the tracking; and latency, meaning the delay between user input (the user moving their head) and sensory feedback (change in perspective) (McMahan et al., 2016). Most modern VR sets utilize the inside-out tracking method (Angelov et al., 2020). However, devices such as the HTC Vive (HTC) and Valve Index (Valve) utilize a marker-based inside-out tracking system that uses additional external sensors to provide better input veracity (Angelov et al., 2020).

2.3 Interacting with the VE

The ability to interact with the VE is an important component of modern VR sets (Angelov et al., 2020; Boletsis, 2017). Interacting with the VE generally consists of two modes of interaction: interacting with objects in the VE and navigating in the VE. How these are achieved and implemented depend on the input devices and the application that is running the VE as well as its control scheme.

2.3.1 Interacting with objects

The ability to interact with objects in the VE as well as the VE itself are important components of modern VR sets (e.g., Angelov et al., 2020; Hudson et al., 2018). Input devices, such as controllers, allow users to directly interact with the VE using natural interaction methods (Angelov et al., 2020; Witmer & Singer, 1998). Users can interact with the VE using various input devices, including traditional, non-immersive devices such as video game controllers (Weech et al., 2019) or keyboards and mice (Lum, Greatbatch, Waldfogle & Benedict, 2018; Martel & Muldner, 2017). Alternatively, modern VR sets allow the use of more natural methods of interaction, such as tracked controllers, hand gestures, or hands by utilizing hand tracking (Angelov et al., 2020; Han & Kim, 2017; Lee, Kim & Kim, 2017; Lum et al., 2018). Modern VR sets usually come bundled with controllers (e.g., Valve, HTC, Oculus) that utilize the same tracking methods mentioned earlier, typically offering 6-DOF positional tracking (Angelov et al., 2020). In addition, controllers not only function as input devices, but can also provide the user with tactile feedback (Angelov et al., 2020). This tactile feedback could be achieved with the use of haptic systems, which would allow the user to not only interact with objects in the VE, but also touch and feel them (Han & Kim, 2017; Kim, Jeon & Kim, 2017).

2.3.2 Navigation

In addition to interacting with objects in the VE, navigating in the VE is another crucial component of interaction (Boletsis, 2017; Boletsis & Cedergren, 2019, Slater, Usoh & Steed, 1995). In prior research, the term (VR) locomotion has been used to describe methods for navigating VEs (Slater et al., 1995). VR locomotion has been widely studied topic since the early days of VR (Boletsis, 2017). The resurgence of VR and the technological advancements that came along with it have led to both new locomotion techniques, as well as significant updates to previous ones (Boletsis, 2017). Unlike the previously mentioned components of modern VR sets, the different locomotion techniques are application based (Boletsis, 2017). It is up to the software developers to decide which locomotion techniques are implemented and how. However, the technology of the VR sets plays a role in which locomotion techniques can be implemented, since certain locomotion techniques require either certain methods for tracking or, for example, 6-DOF to operate (Boletsis, 2017; Boletsis & Cedergren, 2019).

The way locomotion techniques are implemented is also dependent on the control scheme of the VR set (Martel & Muldner, 2017). In their article, Martel and Muldner (2017) examined the performance of the two main approaches to

VR control schemes, which are the coupled scheme and the decoupled scheme. The authors stated that in a coupled scheme, the user perspective and the direction of movement are coupled, meaning that the user moves in the direction the user is facing (Martel & Muldner, 2017). Adversely, in a decoupled scheme, the user can rotate their viewpoint and steer their movement separately (Martel & Muldner, 2017).

Boletsis (2017) identified prevalent VR locomotion techniques from previous literature and categorized them into four distinct VR locomotion types based on the type of interaction, the type of motion and the space the interaction takes place (Boletsis, 2017). These four types of VR locomotion are motion-based, room scale-based, controller-based, and teleportation-based (Boletsis, 2017). Motion-based VR locomotion techniques utilize physical movements to enable navigation, for example, users can move in the virtual environment by walking in place or by swinging their arms (Boletsis, 2017). Room scale-based techniques utilize the ability of the VR set to track the position of the HMD, meaning that users can move in the virtual environment by physically moving in the physical environment (Boletsis, 2017). Controller-based techniques utilize controllers to artificially move the user in the VE for example allowing the users to move using a joystick much like in traditional video games. Teleportation-based techniques enable users to instantly jump between points within the VE (Boletsis, 2017). Each of these types include one or several locomotion techniques, and each offer different advantages and disadvantages (Boletsis, 2017). For example, controller-based techniques are not as physically demanding as motion or room scale-based techniques because users can remain physically stationary while moving in the VE, however, these techniques can more easily cause cyber sickness (Boletsis, 2017). Alternatively, room scale-based techniques allow for continuous movement, but these techniques are limited by the size of the physical environment (Boletsis, 2017). Boletsis (2017) found that VR locomotion types that allow for continuous, uninterrupted movement were strongly preferred according to prior research, that is motion-based, room scale-based, and controller-based techniques.

2.4 Applications for VR

As VR technology is finally catching up to the fidelity and mass availability that was promised during the 1980s and 1990s, it presents a potential for a significant benefit and impact to society (Slater & Sanchez-Vives, 2016; Hudson et al., 2018). Slater and Sanchez-Vives (2016) even suggested that VR could completely transform how some fields operate. In addition, Pallavicini et al. (2019) suggested that VR technology has enormous potential in various fields due to its ability to engage more deeply with the user than most traditional mediums, as well as its ability to provide authentic experiences in virtual environments that can depict real or imaginary settings and scenarios (Pallavicini et al., 2019; Slater & Sanchez-Vives, 2016).

Slater and Sanchez-Vives (2016) presented in their article various fields in which VR is hypothesized to provide significant benefits. For example, the ability of VR to allow users experience 3D spaces allows for enhanced data visualization. This, according to Slater and Sanchez-Vives (2016), will benefit a multitude of fields that deal with increasingly complicated datasets and complex models. Slater and Sanchez-Vives (2016) referenced a study done by Norrby, Grebner, Eriksson, and Bostrom (2015) as an example, in which they found VR effective in drug design by allowing users to examine and interact with 3D visualizations of molecules and cells. Slater and Sanchez-Vives (2016) also reference a study by Lawson, Salanitri, and Waterfield (2016), in which the authors examined the use of VR in car manufacturing. The authors stated that VR has a lot of potential for the manufacturing process because it allows an easy and cost-efficient method for creating new designs without needing to build physical mockups (Slater & Sanchez-Vives, 2016). Furthermore, VR has already been proven effective for fields such as psychotherapy, psychology, neuroscience, education, physical training, travel, industry, and entertainment, just to name a few (Slater & Sanchez-Vives, 2016; Servotte et al., 2020; Lan, 2020; Kim & Biocca, 2018; Bowman & McMahan, 2007). For example, VR has been effectively used to treat phobias by administering exposure therapy through VR and train soldiers in urban combat tactics as a replacement for real-life combat exercises (Bowman & McMahan, 2007).

One of the more promising aspects of VR is its ability to enable experiments that would be impossible to perform in reality, for example studies in social psychology that could not be performed for practical or ethical reasons, as well its ability to train users for situations that are difficult or impossible to recreate in a training setting, for example surgery or disaster medicine (Slater, 2018; Slater & Sanchez-Vives, 2016; Servotte et al., 2020; Mehrfard et al., 2019). The effectiveness of studying users' reactions to different scenarios in VR relies on the sense of presence, meaning a sense of "being" in the virtual environment, which leads to users behaving and reacting to simulated situations as they would in real-life (Slater & Sanchez-Vives, 2016; Slater, 2018). In addition, training in VR has been proven effective in multiple studies across multiple fields (e.g., Cummings & Bailenson, 2016; Slater & Sanchez-Vives, 2016; Suh & Prophet, 2018). For example, Pausch et al. (1997) found that practicing a search task in VR improves performance when the same task is done using a desktop interface and Slater and Sanchez-Vives (2016) reported that a prior study found that VR-trained surgeons performed significantly faster and with less errors than traditionally trained surgeons.

Slater and Sanchez-Vives (2016) suggested that, even though VR will be utilized as a form of entertainment for most private consumers, advancements in VR will have an impact on a number of professional and research fields. The authors emphasized that VR as a medium is still young, and as the technology becomes more affordable and more widespread, it is likely to see a large increase in its range of applications (Slater & Sanchez-Vives, 2016). Slater and Sanchez-Vives (2016) concluded that VR is expected to be revolutionary.

2.5 Cyber sickness

Despite the amount of potential that VR technology has, there are problems the VR industry needs to find a way to overcome (Martirosov & Kopecek, 2017; Weech et al., 2019). One of the most notable and difficult problems with VR use is cyber sickness as it is closely related to our physiology (Martirosov & Kopecek, 2017). The term cyber sickness, also referred to in the literature as simulator sickness (Dużmańska et al., 2018; Witmer & Singer, 1998) or VR sickness (Angelov et al., 2020; Kim et al., 2017; Han & Kim, 2017), refers to an unpleasant feeling that can arise from VR use, and more specifically HMD use (Martirosov & Kopecek, 2017; Suh & Prophet, 2018; Weech et al., 2019). The symptoms of cyber sickness include headaches, nausea, vomiting, fatigue, disorientation, etc. (Martirosov & Kopecek, 2017). Cyber sickness is often said to be closely related to the experience of motion sickness, as they share similar symptoms (Martirosov & Kopecek, 2017; Weech et al., 2019).

The topic of cyber sickness has been long studied in the field of VR (Martirosov & Kopecek, 2017). Literature suggests a number of reasons for what cyber sickness is and why it happens (Weech et al., 2019), but a commonly referenced reason is that it is caused by a mismatch between sensory inputs akin to motion sickness (Martirosov & Kopecek, 2017). Martirosov and Kopecek (2017) suggested that motion sickness happens when the vestibular system detects movement, but you cannot not see it. However, cyber sickness does the opposite, as you see movement when you move in the VE, but your vestibular system does not detect it, causing you to feel sick (Martirosov & Kopecek, 2017).

Prior literature shows that there are a number of factors that influence the appearance and severity of cyber sickness (Dużmańska et al., 2018). For example, prior research has found several individual characteristics such as age, gender, history of migraines and concussions, personality traits such as anxiety and neuroticism, and a susceptibility to visually induced motion sickness influences the likelihood and severity of experiencing cyber sickness (Dużmańska et al., 2018; Martirosov & Kopecek, 2017; Pausch et al., 1997; Weech et al., 2019). Various characteristics of HMDs have also been found to increase cyber sickness, such as high latency caused by low frame rates, high field of view, low frames per second, low refresh rate, the weight of the HMD, stereoscopy, etc. (e.g., Dużmańska et al., 2018; Han & Kim, 2017; Martirosov & Kopecek, 2017; Servotte et al., 2020; Weech et al., 2019). In addition, the length of exposure to the VE, the visual representation of the VE, illusion of self-motion (vection), unnatural control schemes, and navigation methods have also been reported to increase cyber sickness (e.g., Dużmańska et al., 2018; Lee et al., 2017; Slater et al., 1995; Weech et al., 2019).

Cyber sickness is an important problem to solve as it has been reported that it can affect up to 50-80% of VR users and can potentially cause harm to the health of the user (Martirosov & Kopecek, 2017). The modern VR industry has gotten better at managing cyber sickness due to improved visual and interaction fidelity of VR sets (Weech et al., 2019), and the setting of industry standards in managing and limiting vection (Boletsis, 2017; Boletsis & Cedergren, 2019). In addition, Dużmańska et al. (2018) noted that prior studies have shown that while the severity of cyber sickness increases with time, after a certain amount of time, it plateaus or starts to decrease. Repeated exposures have also been noted reduce the effect of cyber sickness (Martirosov & Kopecek, 2017). However, some have suggested that while cyber sickness can be alleviated as VR sets improve, it cannot be completely erased as it is inherently tied to the nature of the technology (Martirosov & Kopecek, 2017). Nevertheless, Martirosov and Kopecek (2017) concluded that as VR will become more prevalent in society, the issue of cyber sickness will have to be resolved.

3 IMMERSION

This chapter introduces the concept of immersion and explores the various ways the term has been defined in the past. It explores the two most fundamentally different views on immersion that are relevant to the topic of this thesis: immersion as an objective property of the technology/system and immersion as a subjective experience and examines their relationship. Finally, it presents two concepts closely related to immersion that are relevant to this thesis and explores their relationship with the concept.

3.1 What is immersion

Nowadays, the use of the term immersion has become commonplace and is widely used in various fields, such as music, film, and literacy, but its use is especially prevalent when talking about video games and VR (Shin, 2018; Agrawal et al., 2020). In the context of games, it is used by players, reviewers, designers, and researchers alike and is meant as a positive quality of a game (Brown & Cairns, 2004; Ermi & Mäyrä, 2005). However, what the term specifically means is often left unspecified (Brown & Cairns, 2004; Ermi & Mäyrä, 2005; Shin, 2018).

Immersion has been defined in various ways in the several fields that have researched it to mean several different things (Agrawal et al., 2020). Depending on the context or field, different models for measuring or defining immersion use different terms or even the same terms with overlapping, or slightly different meanings (Lee, 2021). This lack of consensus led McMahan (2003) to state that immersion has become an "excessively vague, all-inclusive concept." (McMahan, 2003, pp. 63). Even 17 years later, her comment is still frequently cited (e.g., Arsenault, 2005; Nilsson et al., 2016; Agrawal et al., 2020) and the definition of immersion is still under debate (Agrawal et al., 2020; Lee, 2021). In addition, immersion has been used synonymously with various other concepts, including presence, engagement, involvement, and flow, which has further added to the confusion regarding its definition (Brown & Cairns, 2004; Nilsson et al, 2016; Lee, 2021).

Despite differences in how the term is defined, it is generally understood that immersion involves being surrounded by something (e.g., Ermi & Mäyrä, 2005; McMahan, 2003; Nilsson et al., 2016). Several studies reference Murray's (1997) book, Hamlet on the Holodeck (e.g., Arsenault, 2005; Brooks, 2003; Agrawal et al., 2020; Nilsson et al., 2016; Lee, 2021), which explains the origin of the word, and sheds light to the ambiguity of its use:

> "Immersion is a metaphorical term derived from the physical experience of being submerged in water. We seek the same feeling from a psychologically immersive experience that we do from a plunge in the ocean or swimming pool: the sensation of being surrounded by a completely other reality, as different as water is from air, that takes over all of our attention, our whole perceptual apparatus." (Murray, 1997, p. 98).

In their article, Nilsson et al. (2016) compiled and divided the existing definitions and dimensions of immersion into four general views: immersion as an objective property of the system; immersion as a perceptual response to the system; immersion as a response to the narrative, characters, and the world; and immersion as a response to challenges. However, the most fundamental difference between these existing views of immersion is between the former two: the distinction between immersion as an objective property of the system and immersion as a subjective experience in response to the said system (Nilsson et al., 2016). This thesis will focus on these two perspectives due to their relevance to the research question and prevalence in VR research.

Referring to the explanation by Murray (1997), the two different views focus on different aspects of this statement. Those who view immersion as an objective property of the technology understand immersion as the degree to which the other reality surrounds the user. Alternatively, those who view it as an experience view immersion as the individual experience of being submerged in that reality (Nilsson et al., 2016).

3.1.1 Immersion as an objective property of the system

Especially in VR research, the viewpoint that immersion is an objective quality of the system has been commonly adopted (e.g., Bowman & McMahan, 2007; Cummings & Bailenson, 2016; Slater & Willbur, 1997; Slater, 2003; Slater, 2018; Narayan et al., 2005). This has led to the term immersive becoming a popular marketing term for XR technologies (Lee, 2021) and the term immersion has been commonly used to describe VR (Shin, 2018). This definition was originally proposed by Slater (2003), who presented his view of immersion as such:

> "Let's reserve the term 'immersion' to stand simply for what the technology delivers from an objective point of view. The more that a system delivers displays (in all sensory modalities) and tracking that preserves fidelity in relation to their equivalent real-world sensory modalities, the more that it is 'immersive'." (Slater, 2003, p. 1).

Therefore, the immersiveness, or in other words the level of immersion a technology provides, is dictated by its sensory fidelity and its ability to block out external stimuli (Cummings & Bailenson, 2016; Slater, 2003; Slater & Wilbur, 1997). This means that a system can be more or less immersive depending on, for example, the number of sensory modalities it covers, how accurate the simulation is to real life, the naturalness of interactions with the system, and to what extent the external reality is shut out (Cummings & Bailenson, 2016; Slater, 2003; Slater & Wilbur, 1997). Therefore, different technologies can provide different levels of immersion, for example a game played on a computer monitor would be considered less immersive than a game played with a VR set (Pallavicini et al., 2019). This view on immersion is closely tied to the concept of presence, which will be discussed further in the next subsection (Chapter 3.2). In this thesis, for the sake of clarity, this view of immersion is henceforth referred to as technological immersion.

3.1.2 Immersion as a subjective experience

The other view of immersion defines it as a subjective experience (Nilsson et al., 2016). Immersion as a psychological experience has been defined in a number of ways (e.g., Lee, 2021; Pallavicini et al., 2019). For example, Witmer and Singer (1998) defined immersion as a: "psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli and experiences" (Witmer & Singer, 1998, p. 227). Agrawal et al. (2020) defined it as: "a state of deep mental involvement in which the subject may experience disassociation from the awareness of the physical world due to a shift in their attentional state" (Agrawal et al., 2020, p. 407). Cairns et al. (2014) simply as: "the engagement or involvement a person feels as a result of playing a digital game" (Cairns et al., 2014, p. 2). As can be seen from these definitions, the experience of immersion is a complicated phenomenon.

This complexity has led to researchers to define immersion as a multidimensional construct and separate it into various dimensions (Lee, 2021; Nilsson et al., 2016). For example, Ermi and Mäyrä (2005) separated immersion into three dimensions: sensory, imaginative, and challenge-based immersion; Ryan (2003) into narrative and ludic immersion; and Nilsson et al. (2016) into challenge-based immersion, narrative immersion, and system immersion. It is important to note that many of these constructs include either the fidelity of the technology or the user's perception of the technology as a dimension (Lee, 2021). As an example, Ermi and Mäyrä (2005) introduced sensory immersion, which the authors described as the audiovisual execution of games that captures the user's senses. For the sake of differentiating this view of immersion from technological immersion, it is referenced in this thesis as immersion as an experience, or the experience of immersion.

3.1.3 Relating the views of immersion

More recent studies have acknowledged the existence of both views and have suggested how they can coexist and how they relate to each other. Hudson et al. (2018) argued that the objective, technology-based definition of immersion can still be utilized to describe the level of immersion a system provides with the assumption that subjective immersion follows. Skarbez, Brooks, and Whitton (2017) stated that both views are clearly related, and the authors argued that the quality of the technology influences the subjective experience of immersion. This was also suggested by Agrawal et al. (2020), who stated that the technology and its fidelity facilitate the experience of immersion. The authors added that the technology does not guarantee that a user experiences immersion, but it prevents their attention from shifting from the VE, therefore influencing immersion (Agrawal et al., 2020). Furthermore, Mütterlein (2018) also suggested that the experience of immersion is based on and restricted by the technological capabilities of the system, however, it must be measured at a subjective level. These arguments highlight the proposed relationship between these two opposing views. In summary, technology facilitates the experience of immersion, therefore the qualities of the technology can influence the experience of immersion (Agrawal et al., 2020; Hudson et al., 2018; Lee, 2021; Mütterlein, 2018; Skarbez et al., 2017). This relationship is also highlighted by the several conceptualizations of immersion as a multidimensional construct mentioned earlier (e.g., Ermi & Mäyrä, 2005; Lee, 2021; Nilsson et al., 2016).

However, it is important to note that technology is not the only factor that contributes to immersion (e.g., Agrawal et al., 2020; Lee, 2021). Lee (2021) highlighted the role of various subjective factors in influencing the experience of immersion, and this has been confirmed by various studies (e.g., Agrawal et al., 2020; Cairns et al., 2014). For example, Witmer and Singer (1998) stated that several subjective factors, such as the character trait of immersive tendency, meaning a users' inclination to experience immersion, the mental state of the individual, as well as personal preferences on the content they are experiencing have a significant impact on the experience of immersion (Lee, 2021; Witmer & Singer, 1998).

For the purposes of this thesis, a conceptual model of the experience of immersion proposed by Lee (2021) is utilized. The author presents the concept of the experience of immersion as a multidimensional construct consisting of physical presence, social/self presence, and involvement (Lee, 2021). The reasons for using this model in this thesis as well as the model itself will be further explained in the next chapter (Chapter 4.1).

3.2 Related concepts

As mentioned previously, various concepts have been used as synonyms for immersion in past research (e.g., Agrawal et al., 2020; Brown & Cairns, 2004; Nilsson et al., 2016; Skarbez et al., 2017; Lee, 2021). This subchapter presents two prominent concepts from the examined literature which are relevant to the conceptual model used in this thesis: presence and involvement (e.g., Jennett et al., 2008; Lee, 2021; Nilsson et al., 2016; Skarbez et al., 2017). Depending on how they are defined, they can have significant overlap with immersion (Jennett et al., 2008). In addition, prior studies have shown that the relationships between these concepts are complicated, and furthermore, they can influence one another (Mütterlein, 2018; Shin, 2018; Lee, 2021). Regardless, each of these concepts have aspects that clearly separate them from immersion and establish them as separate concepts (Jennett et al., 2008; Shin, 2018; Hudson et al., 2018). However, it is important to note that this is by no means an exhaustive list of related concepts, as the scope of this thesis does not allow for an exhaustive examination.

3.2.1 Presence

In the context of VR, presence has been widely researched over the past few decades (Agrawal et al., 2020; Cummings & Bailenson, 2016; Jennett et al., 2008). Weech et al. (2019) stated that achieving presence is a defining characteristic for VR and Skarbez et al. (2017) stated that presence has been used both as a desired outcome of interacting with VEs as well as a way to measure their quality. However, presence has also been researched in various fields, such as cognitive science, psychology, and computer science (Nilsson et al., 2016). Much like immersion, the term presence has been defined in a multitude of ways and its definition is under debate (Jennett et al., 2008). A commonly used definition of presence defines it as perceptual illusion where a user feels as if they are "being there" (in a virtual environment) (e.g., Cummings & Bailenson, 2016; Kim et al., 2017). This definition follows the example of Slater (2003), who viewed presence as a psychological state. Slater (2003) suggested that the sense of presence is based on the mechanism of making perceptual hypotheses. Simply put, the mind interprets perceptual stimulation from the environment, and based on this stimulation, makes a hypothesis of its location (Slater, 2003). Presence then occurs when the stimuli produced by the technology overpowers the stimuli from the real world (Slater, 2003). This creates the illusion of presence, where the mind thinks it is located in the VE despite knowing that it is virtual (Cairns et al., 2014; Slater, 2018). Slater (2018) states that it is because of this perceptual illusion users react to virtual stimulus the same way they would act to real stimulus. The author explained that, for example, when our perceptual system detects a threat, the brain-body system automatically reacts to it. Only after the reaction does our cognitive system realize that the threat was not real (Slater, 2018). This is what makes presence such a powerful tool and why achieving presence is so highly valued, especially in the context of VR (Weech et al., 2019).

Additionally, much like immersion, presence has been defined as a multi-dimensional construct (Lee, 2021). Lombard and Ditton (1997) defined presence as "the perceptual illusion of nonmediation" and separated it into six different forms that comprise the sense of presence: social richness of the interaction, sense of being a social actor within the environment, sense that the environment and actors within it are also social actors, sense of realism of the VE, sense of transportation, and sense of immersion. The first three of these constitutes a sense of social presence, and the latter three spatial presence (Cairns et al., 2014; Lombard & Ditton, 1997). Note that spatial presence corresponds with the concept of immersion as an experience (Cairns et al., 2014). Alternatively, another widely cited typology of presence was presented by Biocca (1997) (Lee, 2021). He separated presence into three types: physical, social, and self presence. Physical presence refers to a sense of being in the VE (Biocca, 1997; Lee, 2021). Lee (2021) states that this type of presence is what is commonly referred to as what emerges from the sensory stimulation presented by the technology. Social presence refers to a sense of being together and interacting with other intelligences (Biocca, 1997; Lee, 2021). This encompasses both perceptual and cognitive experiences. (Lee, 2021). Finally, self presence refers to the mental models of the user as well as their physiological and emotional states in the VE (Lee, 2021). Simply put, this means that the user's virtual self is experienced as the actual self (Lee, 2021).

A connection between immersion and presence has been suggested but investigating it has been difficult due to differing views on the definitions and measures (Mütterlein, 2018). As mentioned previously, especially in VR research, technological immersion has been commonly used and presence has been defined as the user's subjective experience of this technology, or in other words, the psychological experience of "being there" (Cummings & Bailenson, 2016; Slater & Wilbur, 1997). It is important to note that the "sense of being there" has been classified as one of the features of the experience of immersion (Jennett et al., 2008). A questionnaire for measuring the sense of presence created by Witmer and Singer (1998) found that the naturalness of interactions, how closely they mimic real-world experiences, and how much of the external environment is isolated affected the sense of presence (Jennett et al., 2008; Witmer & Singer, 1998). As can be seen, these factors closely resemble what Slater (2003) defined as (technological) immersion. Slater (2009) stated that technological immersion presents the boundaries in which presence can occur. In other words, technological immersion enables presence (Skarbez et al., 2017). A meta-analysis conducted by Cummings and Bailenson (2016) also found that technological immersion influences presence.

Despite the similarities between the experience of immersion and presence, it has been argued that presence has components that clearly separate the two (Cairns et al., 2014; Jennett et al., 2008). Hudson et al. (2018) argued that immersion is a broader concept than presence. The authors explained this by stating that immersion can occur for example while reading a book or solving mathematical problems, where presence is not necessarily experienced (Hudson et al., 2018). This was also argued by Jennett et al. (2008), who proposed that there is a double disassociation between presence and immersion. For example, a person can be immersed when listening to music, but may not feel present due to lack of visual stimulus (Jennett et al., 2008). Additionally, a user can get immersed while playing a game like Tetris on a 2D screen, but not feel presence since there is no environment for the user to feel present in (Jennett et al., 2008). On the other hand, presence can be achieved without the user feeling immersed (Jennett et al., 2008). For example, a user might feel present while performing a simple task in VR, while not being immersed due to not being mentally involved (Jennett et al., 2008). Jennett et al. (2008) differentiate immersion and presence by stating that presence is a state of mind, whereas immersion is an experience.

Alternatively, in the theory of immersion proposed by Brown and Cairns (2004), the authors referred to the final stage of immersion (total immersion) as presence. Cairns et al. (2014) suggest that specific states of immersive experiences should influence presence. Furthermore, Mütterlein (2018) confirmed a positive correlation between presence and the experience of immersion. It is important to note, however, that Mütterlein (2018) used a more simplified definition of presence, limiting it to its core feature of "sense of being present in another place", and a flow-based conceptualization of immersion which focuses on interacting with the VE.

It is clear from the prior research that the fidelity of the technology, in other words, technological immersion, influences presence (Angelov et al., 2020; Cummings & Bailenson, 2016; Pallavicini et al., 2019; Lee, 2021). However, the relationship between presence and immersion as an experience is complicated (Cairns et al., 2014). The argument presented by Mütterlein (2018) seems to suggest that presence and interaction are significant factors for the experience of immersion. Furthermore, this was also suggested by Lee (2021), who stated that presence is a main component of the experience of immersion. The author argued that various definitions of the experience of immersion consider the definitions of presence as a component (Lee, 2021). For example, sensory and challenge-based immersion by Ermi and Mäyrä (2005) and perceptual immersion by Lombard and Ditton (1997) relate to the concept of presence (Lee, 2021). Lee (2021) stated that presence is what the technology aims for, but the experience of immersion requires both mental and physical involvement in addition to presence.

3.2.2 Involvement

Witmer and Singer (1998) defined involvement as: "a psychological state experienced as a consequence of focusing one's energy and attention on a coherent set of stimuli or meaningfully related events." (Witmer & Singer, 1998, pp. 227). This definition shares similarities with the concept of immersion as an experience (Agrawal et al., 2020). Much like immersion and presence, involvement has been defined in a number of ways. To complicate matters further, the concepts of immersion as an experience and involvement have been used interchangeably in the past (Agrawal et al., 2020; Lee, 2021; Nilsson et al., 2016; Witmer & Singer, 1998), and the concept of involvement is often included in the definition of immersion (e.g., Agrawal et al., 2020; Brown & Cairns, 2004; Cairns et al., 2014). Brown and Cairns (2004) proposed that reaching immersion is a three-stage process, during which the user must reach different levels of involvement with a game to achieve immersion. Cairns et al. (2014) stated that immersion is an experience which is characterized as the degree of involvement users feel towards the game, which results in a shift of focus from the real world towards the game. This shift of focus leads to the user feeling disassociated from the real world, or "losing" themselves in the game, i.e., immersion (Cairns et al., 2014). Agrawal et al. (2020) stated that immersion is something that occurs when the user is deeply involved. However, all the definitions suggest that there is a clear relationship between immersion and involvement. More specifically, all the definitions state that involvement leads to immersion. This relationship has been confirmed in a number of studies. Jennett et al. (2008) found in their study that involvement is a component of immersion, Cairns et al. (2014) suggested that involvement leads to immersion, and Agrawal et al. (2020) stated that absorption (i.e., involvement) leads to immersion. In addition, Lee (2021) suggested that immersion is a higher-level concept that includes involvement as one of its dimensions. Then, in the context of this thesis, involvement is considered a component of the experience of immersion.

4 IMMERSION IN VIRTUAL REALITY

This chapter explores the concept of immersion in the context of VR. First, it presents a conceptual model of the experience of immersion proposed by Lee (2021). Second, it explores prior research and presents four categories of factors that have been found to influence the different dimensions of experience of immerison according to Lee's (2021) model. Third, the findings of the literature review are summarized and the four categories of factors are related to Lee's (2021) model. Finally, hypotheses derived from Lee's (2021) article are presented.

4.1 Role of immersion and presence in VR

As mentioned previously, the majority of research on immersion in the context of VR follow Slater's (2003) view and define it as an objective quality of the system (e.g., Bowman & McMahan, 2007; Cummings & Bailenson, 2016; Slater & Willbur, 1997; Slater, 2003; Slater, 2018; Narayan et al., 2005). Furthermore, the prevalence of the concept of presence in VR research necessitates its inclusion when examining immersion in VR. This was also suggested by Mütterlein (2018) who stated that presence and immersion should be considered together to comprehensively explore VR. Studies have only recently started to examine the relationships between technological immersion, immersion as an experience, and presence (e.g., Agrawal et al., 2020; Skarbez et al., 2017; Lee, 2021; Mütterlein, 2018).

Due to the lack of studies on the experience of immersion in the context of VR, understanding the relationships between these concepts is a necessary step for understanding the experience of immersion in the context of VR. As mentioned previously, no consensus was found in the literature regarding their relationship, however the results reported by Mütterlein (2018) and arguments made by Lee (2021) seem to suggest that presence is a component of the experience of immersion. For this reason, in this thesis, a conceptual model of immersive experience proposed by Lee (2021) is utilized, which is presented in figure 2 (Figure 2). This model provides a comprehensive hierarchical structure for the immersive experience (IE) (Lee, 2021) i.e., experience of immersion, which he proposed consists of three dimensions: physical presence (PP), social/self presence (SP), and involvement (INV), their relationships with the properties of the technology and content, as well as subjective factors that influence them (Lee, 2021). Lee (2021) argued that while different definitions of immersion contain all three dimensions, the conceptualizations tend to only focus on a single dimension of the experience. For example, the definition of immersion by Witmer and Singer (1998) presented in chapter 3.1 focuses on the perceptual aspect of immersion but neglects the cognitive aspect of the experience. Alternatively, the definitions of Cairns et al. (2014) and Agrawal et al. (2020) presented earlier state that immersion results from involvement, however, these definitions ignore the perceptual aspect of the experience (Lee, 2021). This model was chosen due to it being specifically made with XR technologies in mind and because it provides a comprehensive model of the relationships between the experience of immersion, which has been rarely explored in VR literature, technological immersion, presence, and involvement (Lee, 2021). Furthermore, studies that have explored these relationships, the experience of immersion, and its dimensions have reported results that agree with Lee’s (2021) conceptualization (e.g., Mütterlein, 2019; Suh & Prophet, 2018).

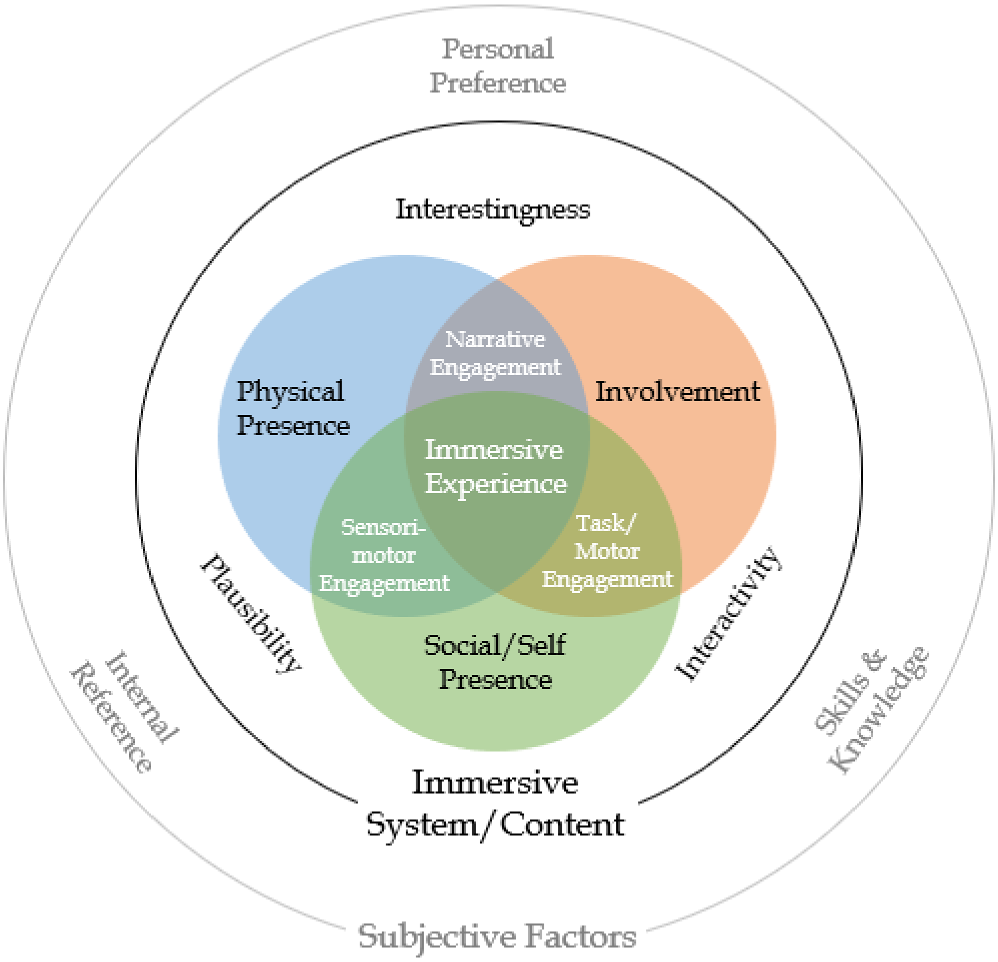

FIGURE 2: Conceptual model of the experience of immersion (Lee, 2021, p. 10)

This conceptual model is built from various conceptual models of immersion (e.g., Brown & Cairns, 2004; Ermi & Mäyrä, 2005; Arsenault, 2005) as well a commonly cited presence typology introduced by Biocca (1997) (Lee, 2021). As presented in the model, the experience of immersion consists of three dimensions: PP, SP, and INV (Lee, 2021). The first dimension is PP, which is typically defined as a sense of "being there" in the VE (Lee, 2021). The author states that PP is often understood as a direct result from sensory stimulation provided by the technology; the higher level of technological immersion the system provides, the higher level of physical presence it provides (Lee, 2021). This is related to Slater's (2003) definition of presence and its relationship with technological immersion. However, Lee (2021) argues that achieving PP does not automatically occur from visual stimulus alone: it also requires a cognitive process to make sense of the VE. In addition, Lee (2021) argues that ability to interact with the VE is important for achieving PP. The second factor consists of two inter-related concepts: social presence and self presence. Social presence is defined as a "sense of being together and interacting with another intelligence" (Biocca, 1997). Lee (2021) states that this definition involves of both perceptual and cognitive experiences. The degree of social presence is determined by the level of interactivity the user has with said intelligences, as well as the user's ability to sense the presence of these intelligences (Lee, 2021). It is important to note that intelligences in this case can refer to either computer generated characters that can interact with the user or virtual representations of other users (Biocca, 1997; Lee, 2021). Self presence is concerned with the user's mental model of themselves inside the VE as well as their physiological and emotional states, meaning that the virtual self is experienced as the actual self (Biocca, 1997; Lee, 2021). Lee (2021) states, that self presence also occurs as both perceptual and cognitive experiences. Furthermore, Lee (2021) suggested that while social and self presence are considered a single factor in the model, he hypothesized that social interactions with other people in the VE should lead to a stronger sense of self presence. The final factor of the immersive experience is INV, which is defined as a psychological experience caused by focusing on certain stimuli, task, event, or narrative (Lee, 2021). These three dimensions influence each other and together contribute to the level of the immersive experience (IE) i.e., experience of immersion (Lee, 2021).

Lee (2021) stated that these three dimensions share components with each other, and these points of overlap the author dubbed sensorimotor engagement between PP and SP, narrative engagement between PP and INV, and task/motor engagement between SP and INV. In the context of this model, these different types of engagement are meant as the initial step in achieving PP, SP, and INV. Sensorimotor engagement means that for the user to feel like they are in a VE with or without other intelligences, the user's sensory channels as well as their motor channels should be engaged by the VE stimulus (Lee, 2021). Lee (2021) emphasizes that sensory stimuli is required to engage the user with the VE. Lee (2021) poses that task/motor engagement, meaning cognitive or physical interactions with the virtual self or other intelligences, enhances SP and INV by engaging the users' mind and motor channels. Lee (2021) referenced various articles that have stated engagement with a narrative as a crucial condition for INV. In addition, the author stated that narrative engagement has also been shown to lead to a sense of being in the VE (PP) (Lee, 2021). Lee (2021) noted that these engagement factors do not directly induce the IE, but that they are the initial stages of PP, SP, and INV.

Furthermore, Lee (2021) proposes that the technology and the content have specific properties that contribute to the different components of IE. This model suggests three properties: plausibility, interactivity, and interestingness. In addition, how these three factors contribute are affected by three subjective factors which are unique to the individual: internal reference, skills and knowledge, and personal preference. Lee (2021) referenced Slater (2009), who defined plausibility as "the overall credibility of the scenario being depicted in comparison with expectations" (Slater, 2009, pp. 3549). Lee (2021) stated that plausibility is not solely dependent on the fidelity of the technology or realism of the content but involves the users' internal reference: internal expectations of what is realistic or what can be expected of the VE. The author differentiates plausibility into two sub-concepts introduced by Lombard and Ditton (1997) (Lee, 2021). These are social realism and perceptual realism, meaning how likely the stimuli would occur in reality and how closely the stimuli matches with the user's expectations of that stimuli happening in reality respectively (Lee, 2021). Lee (2021) proposed that plausibility is related to PP and SP. Interactivity influences both SP and INV in the case of interactive experiences (Lee, 2021). In addition, Lee (2021) suggested that how interactivity affects SP and INV is affected by the skills and knowledge of the user. For example, highly skilled users familiar with the controls and rules of the game would experience a higher level of SP and INV than a beginner (Lee, 2021). Lastly, interestingness refers to the meaningfulness or interest the user has towards the content, which Lee (2021) suggested should increase their level of focus towards the VE, thus leading to an increase in both PP and INV. In addition, Lee (2021) suggests that technology may also influence the user's interestingness towards the content.

Lee (2021) noted that to experience immersion, PP, SP, and INV are not necessary to occur together. He emphasizes that each dimension can independently create the experience of immersion, but the level of the experience will be greater when the dimensions are all contributing individually (Lee, 2021). Lee (2021) hypothesized that the experience of immersion is a quantifiable, graded experience. The level of the experience of immersion, which he dubbed OLIE (overall level of immersive experience) can be determined by the sum of the three dimensions: PP, SP, and INV (Lee, 2021). Then, the OLIE would be highest when all three dimensions reach their highest level individually (Lee, 2021).

However, it is important to note that Lee's (2021) article is currently in preprint, meaning that it has not been peer-reviewed and the model he presented is conceptual as it has not been empirically validated.

4.2 Factors influencing the experience of immersion in VR

The conceptual model presented by Lee (2021) provided the dimensions that collectively make up the experience of immersion. According to the conceptual model, subjective factors (internal reference, personal preference, skills & knowledge), technology and content (plausibility, interestingness, interactivity), influence these dimensions, therefore influence the experience of immersion (Lee, 2021). However, Lee (2021) provided only brief descriptions of these influencing factors. In order to further understand the formation of the experience, a closer examination of these influencing factors is warranted. Here prior literature is examined to find factors related to VR and its use that have been stated to influence either presence, immersion, or involvement. Furthermore, Lee (2021) did not cover factors that negatively influence these dimensions. It is argued here that they are important in providing a comprehensive understanding of the experience of immersion in the context of VR.

It is important to note, however, that different studies referenced here do not follow the same definitions for presence, immersion, or involvement. As mentioned before, in VR research, immersion has been commonly defined as the objective quality of the system (e.g., Cummings & Bailenson, 2016). However, in this thesis, this definition of immersion is referred to as technological immersion, which is considered as a factor that leads to (physical) presence (Lee, 2021). How each of these factors are related to the model will be examined in the next subchapter (Chapter 4.3).

4.2.1 Factors related to interacting with the VE

As Lee (2021) mentioned, the ability to interact with the VE (intelligences, objects) is an important factor in influencing presence and furthermore, the experience of immersion. This has been confirmed by various studies (e.g., Cummings & Bailenson, 2016; Kim & Biocca, 2018). As mentioned in chapter 2.3, tracking in VR allows the user to interact with the VE using natural interaction methods such as using their hands for interacting with objects, using their head to look around, or move their legs to navigate the VE (e.g., Angelov et al., 2020; Boletsis & Cedergren, 2019; Lum et al., 2018). The availability of each of these interaction methods have been linked to increased levels of presence by various studies (e.g., Slater et al., 1995; Boletsis & Cedergren, 2019; Pal et al., 2016; Lee et al., 2017). In addition, the efficiency of the tracking, meaning the speed and accuracy of the user's movements being translated into the VE, as well as the tracking level mentioned in chapter 2.2, have been noted to greatly influence the sense of presence (Angelov et al., 2020; Cummings & Bailenson, 2016; Pal et al., 2016).

Lee (2021) states that a barrier to achieving SP and INV is the users' skills and knowledge. As mentioned previously, tracking allows users to interact with the VE using natural interaction methods (e.g., Lum et al., 2018). It has been suggested that the naturalness of interaction methods would reduce the need to learn new methods for interacting with the VE, which in turn should increase the sense of presence (Witmer & Singer, 1998). Furthermore, both Weech et al. (2019) and Slater et al. (1995) found that intuitiveness of interactions both positively influenced presence and lowered cyber sickness.

Another widely used concept for influencing presence and immersion is multimodality, which refers to the number of senses the user experiences the VE with (Kim et al., 2017). Most modern VR sets enable the user to interact with the VE by providing visual and auditory stimulus, as well as enabling the user to interact with the VE using motion tracked controllers (Angelov et al. 2020). However, Kim et al. (2017) stated that there have been recent studies on methods to involve more of the user's senses. Witmer and Singer (1998) proposed that the completeness and coherence of stimulus for all senses should increase the capabilities to experience presence. This was partially proven by Kim et al. (2017). The authors proposed a hand haptic system, which would allow users to feel the sensation of touch in the VE by utilizing tactile and force feedback, and their study found that this proposed system provided greater presence and immersion (Kim et al., 2017).

For this thesis, the concept of embodiment is included in this category due to its dependency on tracking (Slater & Wilbur, 1997) and its efficacy (Waltemate et al., 2018). Kim and Biocca (2018) defined embodiment as the "degree to which the body of the user is captured, represented, and inside the virtual environment." (Kim & Biocca, 2018, pp. 95). The authors argued that the level of embodiment depends on the degree to which the user's senses are immersed, user's motor activity is tracked, and the ability of the VR set to portray the user's movements within the VE (Kim & Biocca, 2018). This term was also used by Slater and Sanchez-Vives (2016), who defined it as "the process of replacing a person's body by a virtual one" (Slater & Sanchez-Vives, 2016, pp. 8). Embodiment leads to the illusion of virtual body ownership, meaning that the user feels as if a virtually generated body in the VE mapped to their own is their actual body, if the technology and/or content allows it (Slater & Sanchez-Vives, 2016). Waltemate et al. (2018) found that increased technological immersion, coherence between the virtual and the real body, meaning the exactness of the tracking, as well the ability to personalize the virtual body, significantly increased the likelihood of a user experiencing the illusion of virtual body ownership. Waltemate et al. (2018) reported that embodiment and the illusion of virtual body ownership had a positive effect on presence.

4.2.2 Factors related to HMDs

As stated earlier, HMDs are the main component of VR sets. HMDs have been reported to offer various benefits that influence the sense of presence and the experience immersion (e.g., Lum et al., 2018). As mentioned in chapter 2.2, HMDs often contain two separate displays that are viewed through lenses (Angelov et al., 2020). One of the most cited findings from VR studies have indicated that technological immersion, which includes display factors, positively influences presence (e.g., Cummings & Bailenson, 2016; Slater, 2003). However, how these factors affect presence and immersion varies. Display resolution refers to the number of pixels on a display. Higher display resolution increases visual realism and, in combination with pixel density, reduces the screen-door effect (SDE) (Angelov et al., 2020; Cho et al., 2017). In a study conducted by Hou et al. (2012) on screen sizes and viewing angles with traditional monitors, the authors reported that participants who used larger screens experienced greater arousal, mood change and presence. It is important to note that viewing angle and screen size also effects the field-of-view (FoV) for the participant. The effect of FoV has been widely studied in the context of VR. A high FoV value has been reported to have several positive effects, including greater sense of presence and immersion (e.g., Cummings & Bailenson, 2016; Martirosov & Kopecek, 2017; Kim & Biocca, 2018; Martel & Muldner, 2017), increased spatial awareness (Martirosov & Kopecek, 2017), and improved navigation (Nilsson et al., 2016). Notably, Cummings and Bailenson (2016) found in their meta-analysis that FoV, as well as tracking and stereoscopy, had a significantly greater effect on presence than various other factors, including visual fidelity and the inclusion of sound. However, increased FoV has also been found to induce cyber sickness (Angelov et al., 2020; Martirosov & Kopecek, 2017).

Along with tracking and separating the user from the physical environment, stereoscopy is one of the most notable advantages of HMDs to achieving presence and immersion (Cummings & Bailenson, 2016; Lum et al., 2018). As mentioned in chapter 2.2, stereoscopy refers to the visual effect of depth provided by the two separate screens in HMDs that display the VE from slightly different angles (Bowman & McMahan, 2007). In addition to the benefits mentioned previously, stereoscopy has been linked with increased task performance (Bowman & McMahan, 2007). However, stereoscopy has also been reported to increase cyber sickness (Weech et al., 2019). Low frame rates and refresh rates have also been linked to increase in cyber sickness, as well as reduced presence and task performance (e.g., Angelov et al., 2020; Weech et al., 2019). Alternatively, high refresh rates and frames rates have been reported to increase presence (Cummings & Bailenson, 2016; Witmer & Singer, 1998).

As mentioned previously, SDE is an effect that happens when the displays of the HMD are magnified by the lenses, which makes the gaps between the pixels visible to the user. This has been suggested to disturb immersion and presence (Angelov et al., 2020; Cho et al., 2017). Studies have suggested several ways to combat SDE, for example increasing screen resolution and pixel density (Angelov et al., 2020), or using a low-pass optical filter (Cho et al., 2017).

Since HMDs are wearable devices, ergonomics of using them should be considered. Ergonomics refers to the user experience of using an HMD. Examining the ergonomics of HMDs is difficult due to the difficulty of investigating the various, often subjective, factors related to it (Angelov et al., 2020). When comparing commercially available HMDs, both Angelov et al. (2020) and Mehrfard et al. (2019) utilized weight as an objective quality for comparison. Furthermore, it has been reported in prior studies that the weight of the HMD contributes to cyber sickness (Martirosov & Kopecek, 2017). In addition, Servotte et al. (2020) suggested that the weight of the HMD may reduce presence because the weight reminds the user of the existence of the device, thereby taking reducing their presence. As mentioned in chapter 2.1, HMDs can be divided into two classifications, tethered and standalone (Angelov et al., 2020). Angelov et al. (2020) suggested that standalone HMDs provide greater ergonomics due to lack of cables and increased mobility. This increased mobility may increase the sense of presence (Angelov et al., 2020; Servotte et al., 2020). However, Angelov et al. (2020) stated that standalone devices generally offer worse performance in terms of fidelity than tethered HMDs.

Cairns et al. (2014) found that an increase in lighting in a room while playing a game on traditional monitor produced lower levels of immersion than when the lights were off. The authors explained this by stating that the increased lighting makes the user more aware of their surroundings and less engaged with the game (Cairns et al., 2014). A number of studies have reported that the unique ability of HMDs to completely surround the user in the VE and block out external stimuli has been reported to enhance both immersion and presence (e.g., Martel & Muldner, 2017; Witmer & Singer, 1998).

HMDs have been linked to cause cyber sickness (Martirosov & Kopecek, 2017). Cyber sickness has been found to negatively affect both immersion and presence (Weech et al., 2019). As mentioned in chapter 2.5, while the severity of cyber sickness is influenced by a variety of individual characteristics (e.g., Martirosov & Kopecek, 2017), it is ultimately experienced as a result of wearing an HMD. Prior research as noted that various aspects of the technology can increase the likelihood or severity of cyber sickness, such as increased FoV (Angelov et al., 2020; Nilsson et al., 2016; Weech et al., 2019), low refresh rate (Angelov et al., 2020), weight of the HMD (Angelov et al., 2020; Martirosov & Kopecek, 2017), and stereoscopy (Weech et al., 2019).

4.2.3 Factors related to content

Agrawal et al. (2020) stated in their article that the experience of immersion is not merely determined by the technology, but the content plays a significant part as well. However, the authors added that users' responses to different types of content or stimuli may differ due to various individual characteristics or differences (Agrawal et al., 2020; Shin, 2018; Witmer & Singer, 1998). This was also noted by Lee (2021), who stated that the dimensions of INV and PP are influenced by the interest or meaningfulness of the content to the user.

An important factor related to the content is coherence (Skarbez et al., 2017; Witmer & Singer, 1998). Skarbez et al. (2017) stated that though coherence is related to realism, it specifically refers to the consistency of the characteristics, underlying logic, and circumstances of the content, but makes no assumptions of its realness (Skarbez et al., 2017; Witmer & Singer, 1998). Witmer and Singer (1998) stated that coherence of the stimulus is an important component of maintaining a sense of presence, and Skarbez et al. (2017) suggested that coherence contributes to plausibility, which is a crucial component for the illusion of "being there". Furthermore, Lee (2021) presents plausibility as an influencing factor for sensorimotor engagement and the presence dimensions of the experience of immersion.

4.2.4 Factors related to the individual

Various studies have investigated the role of the individual in the experience of immersion. As mentioned previously, users respond differently to different types of content or stimuli (Agrawal et al., 2020). Furthermore, prior research has noted that certain personality traits and individual characteristics influence engagement, presence, and the experience of immersion (e.g., Jennett et al., 2008; Shin, 2018).

Certain personality traits have been found to have an influence on presence and the experience of immersion (Agrawal et al., 2020; Cairns et al., 2014;

Shin, 2018). The most notable trait from prior literature is immersive tendency, which simply refers to the disposition of the user to have immersive experiences (Agrawal et al., 2020; Cairns et al., 2014; Servotte et al., 2020; Witmer & Singer, 1998). Immersive tendency has been linked to increased experience of immersion (Agrawal et al., 2020) as well as increased sense of presence (Hou et al., 2012; Witmer & Singer, 1998).

In addition to personality traits, characteristics of the individual as well as situational factors have also been stated to influence presence and immersion (e.g., Agrawal et al., 2020; Martirosov & Kopecek, 2017; Weech et al., 2019). For example, older users feel more cyber sickness than younger users (Martirosov & Kopecek, 2017), men and individuals with more gaming experience reported higher presence than women (Weech et al., 2019), personal problems or distractions influence the amount of attentional resources a user directs towards the VE, which has been suggested to negatively influence involvement (Witmer & Singer, 1998), and internal references have been suggested to influence PP and SP (Lee, 2021).

Pallavicini and Pepe (2019) found in their study that games played in VR elicited stronger emotional responses compared to games played on a traditional desktop. Shin (2018) suggests that VR allows users to feel closer to the characters and narrative, which can simulate empathy and enhance the strength of experienced emotions. Emotional responses are significant, because strong emotions, both positive and negative, have been recognized as an important component of immersion (Jennett et al., 2008). Therefore, it seems clear that the ability of VR to elicit stronger emotions positively influences immersion and presence (Jennett et al., 2008; Pallavicini et al., 2019; Servotte et al., 2020).

4.3 Summary of the literature review

The purpose of the literature review was to examine how immersion (as an experience) is achieved with modern VR technologies. However, the concept of immersion has been defined in a multitude of ways. As noted in chapter 3.1, majority of VR research utilizes a definition of immersion presented by Slater (2003), who defined immersion as an objective property of the system/technology (e.g., Bowman & McMahan, 2007; Cummings & Bailenson, 2016; Slater & Willbur, 1997). This definition of immersion is referred to in this thesis as technological immersion. An alternative way of viewing immersion considers it as a subjective experience (Nilsson et al., 2016), which is what the research question refers to. However, immersion as an experience has also been defined in various ways (e.g., Agrawal et al., 2020; Witmer & Singer, 1998; Cairns et al., 2014) and explained by breaking it up into various dimensions (e.g., Ermi & Mäyrä, 2005; Arsenault, 2005; Lee, 2021). This variance in definitions between fields of research necessitated the examination of the relationship between these two views. It was noted in the literature that the two views are clearly related (Skarbez et al., 2017), and various studies stated that the technology facilitates the experience of immersion, but it is not the only factor that determines it (Agrawal et al., 2020; Hudson et al., 2018; Lee, 2021; Mütterlein, 2018; Skarbez et al., 2017).

Furthermore, the prevalence of the concept of presence in VR research as well as its similarities to immersion facilitated its closer examination. A common definition describes it as a psychological state where the user has a sense of "being there" in the VE (Cummings & Bailenson, 2016; Slater, 2003). However, much like immersion, presence is a complicated concept with similar problems related to its definition (Jennett et al., 2008) and it has also defined as a multidimensional construct (e.g., Biocca, 1997; Lombard & Ditton, 1997). Furthermore, the experience of immersion and presence share various components depending on their definitions (Jennett et al., 2008), and have been used as synonyms (Brown & Cairns, 2004).

Various authors found that even though the concepts share similarities, they have elements that clearly separate them as different concepts (Cairns et al., 2014; Hudson et al., 2018; Jennett et al., 2008). However, as separate concepts, the relationship between them is complicated (Cairns et al., 2014). Various hypotheses have been made to explain their relationship (Cairns et al., 2014; Mütterlein, 2018), and some studies have found contradictory evidence (e.g., Mütterlein, 2018; Cairns et al., 2014; Waltemate et al., 2018), but from the articles covered in this thesis, no definitive consensus on their relationship was found. However, a few recent articles have suggested that presence is a component of the experience of immersion (Mütterlein, 2018; Lee, 2021). For example, Lee (2021) argued that various proposed dimensions of immersion include the concept of (physical) presence, or the "sense of being" in the VE.

For the purposes of this thesis, a conceptual model of the experience of immersion proposed by Lee (2021) was adopted, in which the experience of immersion consists of three dimensions: physical presence (PP), social/self presence (SP), and involvement (INV). These dimensions influence one another and collectively contribute to the experience of immersion (immersive experience, IE); however they are not required to occur together (Lee, 2021). These dimensions are influenced by individual factors as well as the technology and content in use (Lee, 2021). This model was chosen because it contains the same relationships between technological immersion, presence, and the experience of immersion that were found in recent literature. Furthermore, the model was constructed to be used with XR technologies (Lee, 2021).

This model, in essence, explains how the experience of immersion is achieved in the context of VR technologies. However, whereas Lee (2021) presents general factors that influence the dimensions, the purpose of the literature review was to examine and present specific factors of modern VR technologies and their use which have been stated to influence the experience of immersion or its dimensions from prior research. This was done to provide a more complete understanding of the factors that influence immersion and build upon the model presented by Lee (2021). These factors are divided into four categories:

factors related to interacting with the VE, factors related to HMDs, factors related to content, and factors related to the individual in VR.

4.3.1 Relating the factors to the conceptual model

Table 1 presents the factors found in the literature review that are related to interacting with the VE (Table 1). This includes both perceptual and cognitive factors as well as properties of the technology.

TABLE 1: Factors related to interacting with the VE

Factors related to interacting with the VE	**Description**	**Articles referenced in**
Tracking	Tracking refers to the VR systems ability to track the positions of the user's head, hands and potentially other body parts. Availability and fidelity of tracking has been found to influence immersion and presence.	Angelov et al., 2020; Bowman & McMahan, 2007; Cummings & Bailenson, 2016; Kim & Biocca, 2018; Lee et al., 2017; Pal et al., 2016; Suh & Prophet, 2018; Witmer & Singer, 1998.
Intuitiveness of Controls	The ability of users to interact with the VE using similar motions as in real life has been reported to positively effect immersion and presence.	Boletsis, 2017; Boletsis & Cedergren, 2017; Kim et al., 2017; Lum et al., 2018; Martel & Muldner (2017); McMahan et al., 2016; Slater et al., 1995; Weech et al., 2019; Witmer & Singer, 1998.
Multimodality	Multimodality refers to the amount of senses the user can use to interact with the VE. It has been suggested that the greater amount of senses being coherently stimulated, the greater the sense of presence and immersion.	Cummings & Bailenson, 2016; Kim et al., 2017; Servotte et al., 2020; Witmer & Singer, 1998.
Embodiment	Embodiment refers to the transfer of the user's physical body into the VE as a virtual representation. Various studies have reported that embodiment provides a greater sense of presence.	Kim & Biocca, 2018; Slater et al., 1995; Slater & Wilbur, 1997; Slater & Sanchez-Vives, 2016; Waltemate et al., 2018; Witmer & Singer, 1998.

The factors in this category relate to all three dimensions of the experience of immersion (Lee, 2021). Tracking and the intuitiveness of controls relates to SP and INV. Tracking enables task/motor engagement and the fidelity of the tracking influences how easily users get engaged. As mentioned previously, Lee (2021) argued that intuitiveness of controls lowers the barrier of user's skills and knowledge. Alternatively, both multimodality and embodiment are related to PP and SP. Multimodality allows for deeper sensorimotor engagement by further removing the user from the physical environment (e.g., Witmer & Singer, 1998). Embodiment is closely related to SP, as self presence encompasses the definition of embodiment (Lee, 2021). To achieve embodiment, the user needs to see at least a partial virtual representation of their body in the VE, meaning that sensorimotor engagement is required for embodiment to be experienced (Lee, 2021; Slater & Sanchez-Vives, 2016).

Table 2 presents the factors that are related to HMDs (Table 2). This category includes physical features of modern HMDs as well as their effects that one way or another influence the experience of immersion.

TABLE 2: Factors related to HMDs

Factors related to HMDs	**Description**	**Articles referenced in**
Display properties	Display properties includes factors such as resolution, pixel density, display size, field-of-view, refresh rate, frame rate, and stereoscopy. High-fidelity displays have been linked to improved presence and immersion.	Angelov et al., 2020; Bowman & McMahan, 2007; Cummings & Bailenson, 2016; Hou et al., 2012; Hwang & Kim, 2010; Kim & Biocca, 2018; Lee et al., 2017; Narayan et al., 2005; Nilsson et al., 2016; Martirosov & Kopecek, 2017; Martel & Muldner, 2017; Mehrfard et al., 2019; Morie, 2006; Servotte et al., 2020; Weech et al., 2019; Witmer & Singer, 1998.
Screen-door effect	Screen-door effect (SDE) refers to the visibility of the lines between pixels on the display. This is affected by the resolution and pixel density of the display. It is suspected that SDE reduces immersion and presence	Angelov et al., 2020; Cho et al., 2017; Servotte et al., 2020.
Ergonomics	Ergonomics refers to the physical properties of an HMD, its comfort and user experience of wearing it. Factors such as weight or connections can cause discomfort, leading to reduced involvement.	Angelov et al., 2020; Martirosov & Kopecek, 2017; Mehrfard et al., 2019; Servotte et al., 2020; Suh & Prophet, 2018; Witmer & Singer, 1998.
Blocking out sensory dis-	HMDs have the unique ability to completely isolate the user from the physical	Cairns et al., 2014; Lum et al., 2018; Martel & Muld-

tractions	environment, which has been included in various definitions of both presence and immersion.	ner, 2017; Pallavicini et al., 2019; Suh & Prophet, 2018; Witmer & Singer, 1998.
Cyber Sickness	Cyber sickness is a phenomenon resulting from the use of VR. Studies suggest that cyber sickness is caused by mismatch between sensory inputs and has been reported to decrease presence.	Angelov et al., 2020; Dużmańska et al., 2018; Kim et al., 2017; Lee et al., 2017; Martirosov & Kopecek, 2017; Nilsson et al., 2016; Servotte et al., 2020; Suh & Prophet, 2018; Weech et al., 2019.

Display factors relate to the perceptual aspects of PP and SP. Higher fidelity displays allow for a more realistic and plausible VE, which reduces the cognitive effort required to reach higher levels of both types of presence (Lee, 2021). Alternatively, SDE increases the required cognitive effort and poor ergonomics have been suggested to reduce the level of INV (Witmer & Singer, 1998). HMDs ability to block out external stimuli has been widely suggested to contribute to the sense of "being there" in the VE, meaning that in the context of Lee's (2021) model, it relates to PP, SP, and sensorimotor engagement (Lee, 2021). The causes for cyber sickness are mainly related to display factors and the experience of wearing an HMD (Martirosov & Kopecek, 2017; Servotte et al., 2020), but it has been cited that interacting with the VE can also influence its severity (e.g., Kim et al., 2017). Cyber sickness has been cited to reduce both PP and INV (Servotte et al., 2020). One possible explanation for this is that focus has been stated as a central component for both PP and INV (Lum et al., 2018, Lee, 2021; Witmer & Singer, 1998). It could be argued that symptoms of cyber sickness distract the user from the VE by shifting their focus on their feeling of discomfort, therefore reducing each.

Table 3 presents factors related to the content that have been stated to influence immersion and presence (Table 3). As Lee (2021) suggested, the type of content has been found to influence presence and the experience of immersion (Martirosov & Kopecek, 2017; Suh & Prophet, 2018).

TABLE 3: Factors related to content

Factors related to content	**Description**	**Articles referenced in**
Type of content	It has been noted that the type of the content influences the experience of immersion. Not all stimuli will immerse all users equally.	Agrawal et al., 2020; Martirosov & Kopecek, 2017; Skarbez et al., 2017; Suh & Prophet, 2018.
Coherence	Coherence refers to the consistency of the content. Coherence has been suggested as an important aspect of plausibility.	Skarbez et al., 2017; Witmer & Singer, 1998.

Lee (2021) stated that content influences all the dimensions of the immersive experience. Different types of content are interesting to different users based on their personal preferences, which Lee (2021) posed to influence narrative engagement, thereby influencing INV and PP. In addition, content can influence SP and INV depending on whether it allows for task/motor engagement (Lee, 2021). Finally, as mentioned previously, coherence has been stated as an important component of plausibility (Skarbez et al., 2017), therefore influencing both PP and SP (Lee, 2021).

Table 4 (Table 4) presents factors that are related to the users of VR and their individual characteristics which have been reported to influence immersion and presence.

TABLE 4: Factors related to the individual

Factors related to the individual	**Description**	**Articles referenced in**
Personality traits	The personality trait immersive tendency has been found to significantly influence the experience of immersion and presence.	Agrawal et al., 2020; Cairns et al., 2014; Hou et al., 2012; Shin, 2018; Servotte et al., 2020; Witmer & Singer, 1998.
Individual characteristics and situational factors	Various individual characteristics and situational factors have also been suggested to influence immersion and presence. These include factors such as age, gender, mood, state of mind, etc.	Agrawal et al., 2020; Lum et al., 2018; Narayan et al., 2005; Suh & Prophet, 2018; Weech et al., 2019; Witmer & Singer, 1998.
Emotions	VR has been noted to elicit strong emotional responses in users. Users who reported experiencing strong emotions also reported a higher sense of presence.	Hou et al., 2012; Jennett et al., 2008; Pallavicini & Pepe, 2019; Shin, 2018; Suh & Prophet, 2018; Servotte et al., 2020.

As mentioned by Lee (2021), the factors in this category influence all the dimensions of the experience of immersion. Internal references influence what users consider plausible (plausibility), personal preference influences the persons interest to engage with the content (interestingness), and the user's skills and knowledge, though not mentioned here specifically, influences INV and SP (Lee, 2021).

It is important to note that this is not an exhaustive list of factors related to VR and its use that influence the dimensions of the experience of immersion. However, providing an exhaustive list of influencing factors is not in the scope of this thesis. In addition, not all of these factors have been empirically tested using modern VR sets. It is up to future studies to examine these effects using empirical methods. Nevertheless, this thesis provides a glimpse into the myriad of factors that can potentially influence the experience of immersion in VR.

4.3.2 Hypotheses

While examining the factors presented in the previous subchapter is important to get a more complete view on the experience of immersion in the context of VR, limitations in scope of a master's thesis does not allow for all these factors to be examined. In addition, due to the limitations set by the ongoing COVID-19 pandemic, performing a study in a controlled setting is not feasible, and examining the effects of some of these factors would be difficult using other alternate methods. Furthermore, as the model presented by Lee (2021) is, at this time, purely conceptual and it has not been empirically tested, empirically examining it is of importance before it can be used to examine the factors presented previously. Therefore, the empirical study done in this thesis sought to take the first step in empirically examining the conceptual model of immersion presented by Lee (2021) in his article.

The model presented by Lee (2021) is comprised of 13 variables as presented earlier in chapter 4.1. The model Lee (2021) presented is based on various previous models of the experience of immersion (e.g., Ermi & Mäyrä, 2005; Arsenault, 2005). Lee (2021) proposes that while these models use various adjectives to describe different types of immersion, they connotate the underlying concepts of physical presence (PP), social/self presence (SP) and involvement (INV). These three concepts are the main attributes of the experience of immersion (immersive experience, IE) in Lee's (2021) model. In addition, these three attributes have overlapping sub-components of narrative engagement between PP and INV, sensorimotor engagement between PP and SP, and task/motor engagement between INV and SP. Furthermore, these attributes are related to three properties of the technology in use and content being experienced, which in turn are influenced by subjective factors. Interestingness is related to PP and INV and is influenced by the personal preferences of the user, plausibility is related to PP and SP and is influenced by the user's internal reference, and interactivity is related to SP and INV and influenced by the user's skills and knowledge.

To examine the conceptual model, the model was converted to 10 hypotheses based on Lee's (2021) article and the sources he referenced. Firstly, Lee (2021) proposes that how interesting or how meaningful the content is for the user influences narrative engagement, PP, and INV. Therefore, hypothesis H1abc states that:

- H1abc: Interestingness has a positive effect on PP (H1a) and INV (H1b), and narrative engagement (H1c).

Lee (2021) proposes that engagement with the narrative of content is a primary condition for INV but hypothesizes that it can also contribute to the sense of being in the VE (PP). Hence, hypothesis H2ab states:

- H2ab: Narrative engagement has a positive effect on PP (H2a) and INV (H2b).

Lee (2021) suggests that plausibility is associated with PP and SP. He proposes that high level of presence does not require the VE to be realistic, but is rather related to plausibility, which is influenced by the users' internal reference of what is realistic. Therefore, hypothesis H3abc states:

- H3abc: Plausibility has a positive effect on PP (H3a) and SP (H3b), and sensorimotor engagement (H3c).

Lee (2021) proposes that both PP and SP requires users' sensory and motor channels to be engaged with the VE. He suggests that both types of presence are influenced by sensory input as well as bodily movement (Lee, 2021). Therefore:

- H4ab: Sensorimotor engagement has a positive effect on PP (H4a) and SP (H4b).

Lee (2021) proposes that interactivity serves both SP and INV if the content and technology are interactive. He hypothesizes that SP and INV might be increased if, for example, the technology supports natural interaction methods (Biocca, 1997; Lee, 2021). However, user's skills and knowledge about the controls and rules act as a barrier. Then, hypothesis 5abc states that:

- H5abc: Interactivity has a positive effect on SP (H5a), INV (H5b), and task/motor engagement (H5c).

Lee (2021) hypothesizes that SP can be enhanced by mental or physical interactions between the virtual body of the user and other intelligences in an activity or task. In addition, INV in enhanced by the ability to focus on a task or activity. Therefore, hypothesis 6ab states:

- H6ab: Task/motor engagement has a positive effect on INV (H6a) and SP (H6b).

Lee (2021) proposed that PP, SP, and INV influence each other and collectively contribute to the experience of immersion (immersive experience, IE). Therefore, hypotheses H7, H8, H9, and H10 are as follows:

- H7: PP and INV positively influence each other.

- H8: PP and SP positively influence each other.

- H9: SP and INV positively influence each other.

- H10: PP, SP, and INV positively influence IE.

The hypotheses are presented in figure 3 (Figure 3). Lee (2021) includes that while PP, SP, and INV do not need to occur together to create IE, the individual weighted sums, depending on the type of experience and the technology in use, of PP, SP, and INV make up the overall level of immersive experience (OLIE) (Lee, 2021). The author hypothesizes that OLIE would be highest if all three reached their highest level individually (Lee, 2021). However, examining the concept of OLIE is outside the scope of this thesis, so examining OLIE and the weighting of the variables will have to be examined in future studies.

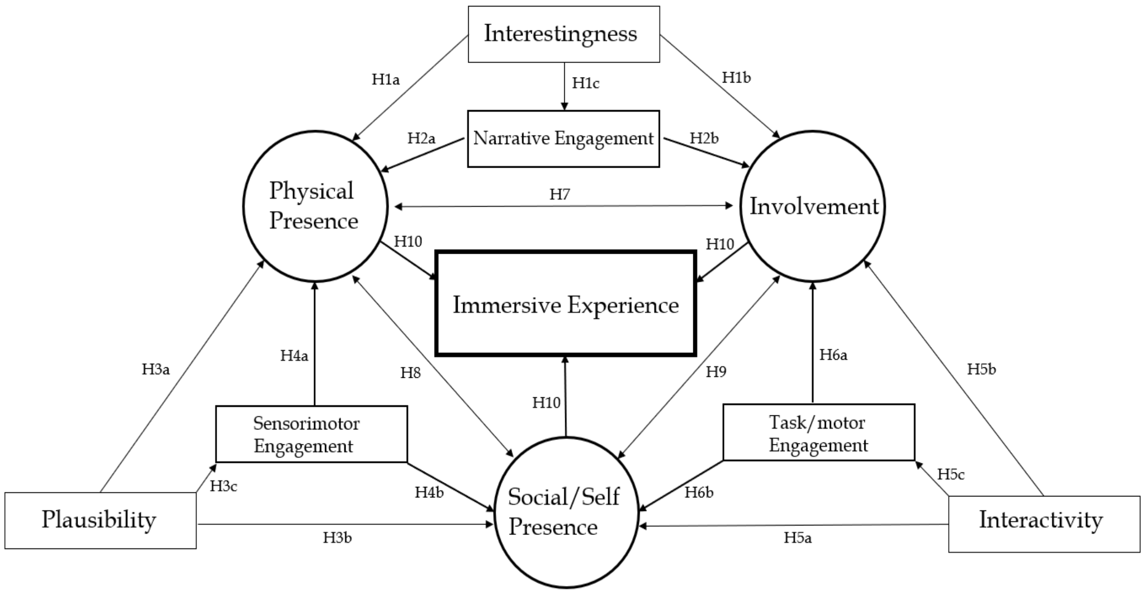

FIGURE 3: Hypotheses

5 EMPIRICAL STUDY

This chapter presents the empirical study done in this thesis. First, the purpose of the study is presented and what the study examined. Next, the chosen method is explained and how the questionnaire form was constructed. Then, the data collection procedure is explained and finally, how the data analysis was conducted.

5.1 Purpose of the empirical study

The literature review conducted in this thesis presented several factors that influence the experience of immersion (Chapter 4). However, due limitations in scope of a master's thesis, as well as concerns raised by the current COVID-19 pandemic, the topic for the empirical study had to be reconsidered. Therefore, the empirical study in this thesis examines the conceptual model of immersion in extended reality presented by Lee (2021), which was explained in greater detail in chapter 4.1. The purpose of the empirical study is to take the first step into empirically examining the conceptual model and the hypotheses derived from Lee's (2021) article. Examining this conceptual model is a necessary initial step towards understanding the experience of immersion with VR technologies and closer examining the factors that influence it. The findings of this thesis could allow for better understanding of the experience of immersion in the field of VR research, allow future researchers to further examine and eventually validate Lee's (2021) model. This could allow the model to be utilized in more closely examining the effects of different factors on the experience of immersion.

Examining this model is significant due to its specialization towards XR technologies. However, it is important to note that the empirical study in this thesis focused on just VR technologies. Furthermore, this model bridges the gap between research on the experience of immersion and presence research by presenting presence as a component of the experience of immersion (Lee, 2021). As mentioned previously (Chapter 3.1), immersion in the field of VR has followed Slater's (2003) definition of being solely tied to the fidelity of the technology in use (e.g., Bowman & McMahan, 2007; Narayan et al., 2005). This difference in definitions between the fields researching the experience of immersion and the fields of presence and VR research has been an ongoing issue and has made examining the concepts difficult (Mütterlein, 2018).

5.2 Method

For examining the hypotheses presented previously (Chapter 4.4), a quantitative study was chosen as the method. The data was collected using an online survey. A quantitative study was chosen due to the prevalence of quantitative studies within the fields of immersion and presence research (e.g., Skarbez et al., 2017; Suh & Prophet, 2018). Prior research has shown it to be a valid method for examining the topic of immersion and presence (e.g., Baños et al., 2000; Jennett et al., 2008; Witmer & Singer, 1998; Suh & Prophet, 2018) despite having received some criticism in the past (Skarbez et al., 2017). The data collection method was chosen for various reasons. Firstly, as modern virtual reality (VR) sets are still relatively new and expensive (McCarthy, 2019), it allowed for a wide reach in terms of participation and a larger quantity of data to be collected than with alternate methods (DeSimone, Harms & DeSimone, 2014). Secondly, performing an experiment in a laboratory setting would have required significant investment in equipment and physical labor, as most VR equipment is expensive and requires a powerful desktop computer to operate (Angelov et al., 2020). Furthermore, the current COVID-19 pandemic raised several concerns regarding health risks, willingness of participation, as well as hygiene concerns considering that VR headsets are worn on the participants face, and operating the device often requires physical effort within a small, enclosed space (Angelov et al., 2020). Due to the data collection method, it was important to keep the questionnaire form short to better keep the attention of the participants, which was expected to increase the number of responses and provide more reliable data. However, this presented additional limitations which will be discussed in the limitations of this thesis (Chapter 7.2).

The data was collected using a structured questionnaire which was built from the hypotheses derived from Lee's (2021) article and the conceptual model. The full questionnaire form is presented in the appendix (Appendix 1), and the construction of the questionnaire and its measures are explained in the next subchapter (Chapter 5.3). A structured questionnaire was used due to questions needing additional explanation, which is presented in the appendix using boldened text (Appendix 1). This was done to provide additional context for questions related to social presence, as the author deemed that viewing both human controlled characters via online play and computer-controlled agents as people might not be intuitively understood.

5.3 Questionnaire

The questionnaire form included 8 control questions (C1-C8), 38 questions on a 5-point Likert scale related to the variables in the model (Q1-Q38), one question related to the experience of immersion on a 10-point Likert scale (Q39), and one question at the end of the questionnaire which asked the participants for their contact email addresses for the purpose of the raffle. The 5-point Likert scale ranged from 1 (Strongly disagree) to 5 (Strongly agree). This was chosen due to it being commonly used in immersion and presence surveys and found to be a reliable measure (e.g., Jennett et al., 2008; Brockmyer et al., 2009; Cheng, She & Annetta, 2014). The measurement scale for question 39 (Q39) ranged from 1 (Not at all immersed) to 10 (Very immersed) as it was presented in the original questionnaire by Jennett et al. (2008). One reversed question (Q3) was included in an effort to improve the reliability of the dataset (DeSimone et al., 2014). The questionnaire form included in total of 48 questions. The full list of questions and their sources are presented in appendix 1 (Appendix 1). The questionnaire form was constructed based on the article presented by Lee (2021) from previously used and validated questionnaires relating to immersion, (physical) presence, social presence, VR experience, engagement, involvement, self presence, and embodiment. In total, 21 questionnaires were examined, and the final set of questions used in the questionnaire (Appendix 1) included questions from 14 questionnaires (Baños et al., 2000; Calvillo-Gamez, Cairns & Cox, 2010; Chertoff, Goldiez & LaViola Jr., 2010; Cheng et al., 2014; Jennett et al., 2008; de Kort, Ijsselsteijn & Poels, 2007; Makransky, Lilleholt & Aaby, 2017; McMahan, Bowman, Zielinski & Brady, 2012; Mütterlein, 2018; Sas & O'Hare, 2003; Schubert et al., 2001; Vorder et al., 2004; Wiebe et al., 2014; Witmer, Jerome & Singer, 2005). In addition, four questions (Q2, Q6, Q8, Q9) were created based on Lee's (2021) article and his description of the variables in the conceptual model.

The control questions were used to collect the sample characteristics (See Appendix 2) as well as for screening participants. The control questions included sample characteristics such as age (C1), gender (C2), previous experience with VR (C3), when the VR experience happened (C4), how long the VR experience lasted (C5), experience genre (C6), screening question about other people in the experience (C7), and which VR set was used (C8).

Lee (2021) stated that the variables sensorimotor engagement, task/motor engagement, and narrative engagement are the initial steps towards physical presence (PP), social/self presence (SP), and involvement (INV). Therefore, three questions were attributed to each of these variables. Questions one through three (Q1-Q3) were meant to determine if the participant's sensory and motor channels were engaged with the virtual environment (VE)'s stimulus. Lee (2021) proposed that the users' senses must be engaged with the VE stimulus for the user to experience PP and SP. Questions four through six (Q4-Q6) were meant to determine if the VE allowed the user to interact with it using their mind and motor channels, since Lee (2021) stated that both SP and INV require the users' mind and motor channels to be engaged. Questions seven through nine (Q7-Q9) were meant to gauge how interested the user was in the narrative and events of the VR content they were experiencing. Lee (2021) proposed that being engaged with the VR content is a prerequisite for INV, but suggested that it could also influence PP.

Lee (2021) stated that subjective factors of personal preference, internal reference, and skills & knowledge, as well as the factors of interestingness, plausibility, and interactivity, which are related to the immersive system (IS) i.e., the VR set, and the content being experienced influence the other variables in the model (Lee, 2021). In this study, interestingness and personal preference, plausibility and internal reference, and interactivity and skills & knowledge were combined. This was done because these variables are inherently tied together. Personal preference influences what type of content the user finds interesting (interestingness), internal reference determines what the user finds plausible (plausibility), and users' skill and knowledge influences their ability to interact with the VE (interactivity) (Lee, 2021). Three questions were attributed to each of these variables.

Lee (2021) described plausibility as the credibility of the VE and the scenario in comparison to the users' expectations. Then, questions 10 through 12 (Q10-Q12) were meant to examine how consistent the VR experience was in regard to the users' expectations of it and the real world. Lee (2021) presented interactivity using an example of a tennis match. He proposed that the realism of controls as well as the users' ability to concentrate on the game instead of the controls and rules of the game would influence their experience of SP and INV (Lee, 2021). Therefore, questions 13 to 15 (Q13-Q15) were meant to examine how proficient the participants were with the controls and rules of the experience, as well as how natural the controls felt. Finally, Lee (2021) described interestingness as simply the users' interest towards the content they are experiencing. He proposed that the more interested a user is towards the content, the more they will be focused on the experience, hence get more involved and more likely to experience a sense of being in the VE (PP) (Lee, 2021). Then, questions 16-18 (Q16-Q18) were meant to gauge how interested the user was in the type of experience, its scenario and the tasks and activities they performed during the experience.

Lee (2021) defined PP as the user feeling as though they are physically present or feeling a sense of "being" in the VE. Five questions in the questionnaire were attributed to examining this experience (Q19-Q23). Questions 24 to 28 (Q24-Q28) were selected to examine the experience of social presence. Lee (2021) defined the base level of social presence as a state in which the user feels that they are in the presence of other people in the VE. In the context of this model, "people" refers to both human controlled characters via online play and computer-controlled characters (Biocca, 1997). Lee (2021) suggested that the level of social presence a user feels rises as they feel that they can access the intelligence of the other people, for example being able to (realistically) interact with them and to understand their intentions. Questions 29 to 33 (Q29-Q33) were included to examine the experience of self presence. Lee (2021) defined self presence as a state in which the user feels as though their physical body is connected to or influenced by the virtual body they are operating. This means a state in which the virtual body and the physical body are physiologically and emotionally connected (Lee, 2021). Furthermore, the users body image and social identity can be influenced by the VE and their virtual body (Biocca, 1997; Lee, 2021). Lee (2021) proposed that social and self presence are interrelated concepts, both of which are contingent on sensorimotor engagement and task/motor engagement, and both are influenced by plausibility and interactivity. Because of this, Lee (2021) presented social and self presence as a single variable (SP) in the conceptual model. Therefore, they are considered as a single variable in this study as well. However, as they are not the same experience, the questionnaire included five questions for each. Questions 34 to 38 (Q34-Q38) examined the concept of INV. Lee (2021) presented INV as a general concept in the model and likened it to concepts such as engrossment (Brown & Cairns, 2004) and cognitive absorption (Agrawal & Karahanna, 2000). Witmer and Singer (1998) defined INV as a state in which the user focuses their energy and attention towards a set of stimuli or related activities or events. For the questions, various involvement, engagement, and immersion questionnaires (e.g., Brockmyer et al., 2009; Cheng et al., 2014; Hudson et al., 2018) were examined and questions were chosen based on repeating concepts. The concept of INV used in this study considers it as a state in which the user is fully focused on the VE stimulus and the tasks or activities the user is performing. Finally, question 39 (Q39) asks how immersed the user felt during the experience. Due to limitations in scope of this thesis as well as concerns about the length of the questionnaire, a simple, one question measure was chosen to examine the experience of immersion. As mentioned previously, the experience of immersion is a complicated phenomenon which is influenced by several factors (e.g., Ermi & Mäyrä, 2005; Nilsson et al., 2016). Therefore, while a single question measure of immersion is not preferrable, it has been validated as a sufficient measure (Jennett et al., 2008).

5.4 Data collection

Before the data was collected, the questionnaire form was presented to the advisor for this thesis as well as one other University of Jyväskylä faculty member. The questionnaire was then tested using two participants, after which three questions were changed to questions with a clearer wording. The dataset was collected using the survey during the spring of 2021 using Google Forms. The users were incentivized to participate in the survey by allowing them to participate in a raffle of two €20 Steam gift cards and one €50 Steam gift card. The responses were limited to one per Google Account to limit users from responding multiple times. The survey was done over the internet, which allowed a large sample of data to be collected, which would have been difficult to collect otherwise (DeSimone et al., 2014). The survey was shared on 12 VR set and VR game specific subreddits on the messaging board website Reddit (Reddit), as well as on five servers of VR specific content creators on the chat application Discord (Discord). The survey was targeted towards VR set owners with moderate to high levels of experience in using a VR set. This target group was chosen as an effort to minimize the effects of unaccounted for factors such as technical difficulties, cyber sickness (Dużmańska et al., 2018), and wow-factor (Pallavicini & Pepe, 2019). Control question three (C3) was used as a screening question, which asked how familiar the users were in using a VR set on a 5-point Likert scale (1=Not at all familiar – 5=Very familiar). The responses of participants who answered either 1 or 2 were excluded from examination.

The participants were asked to fill out the questionnaire based solely on their most recent VR experience. The participants were asked when the VR experience in question happened (C4) and how long the VR experience lasted (C5). Participants who answered that the experience happened over a week ago were excluded from the examination as a significant amount of time between the experience and answering the questionnaire could influence the results (Weech et al., 2019). Furthermore, participants who answered C5 that the experience lasted less than 30 minutes were also excluded, as this improved the reliability of the data and excluded participants whose experience did not last more than a few minutes. Finally, control question seven (C7) asked participants whether there were other people, in the context of the study meaning both human controlled characters and computer-controlled agents, in the virtual environment (VE) with them. Participants who answered negatively were excluded from the examination. This was done because for SP to be experienced, there must be other people in the VE as social presence is induced through the presence of other people and interaction with them (Lee, 2021; Skarbez et al., 2017).

In total, there were 683 participants in the survey. No missing or faulty datasets were found as all questions were mandatory (C1-C8 and Q1-Q39) to submit the answers. The data was screened for nonvariant responses before the reverse scale was inverted, which removed the responses of users who answered the same item to every question (Q1-Q38) (DeSimone et al., 2014). This was done using Microsoft Excel by removing the entries from participants whose standard deviation among the responses was 0. This resulted in 20 participants being excluded from the examination. In addition, 316 participants were excluded according to the screening procedures mentioned above. Therefore, the final examination included 347 participants, which is still well above the recommended minimum sample size (N) of 200 (Guilford, 1956).

Out of the final dataset, sample characteristics for age, gender, which VR set participants used, and what genre of game/experience their response was based on were calculated. The most significant sample characteristics are presented in table 5 (Table 5) and full sample characteristics are shown in the appendix (Appendix 2). As shown in the table, 41,5% of participants were ages between 18-24, 32,3% were 25-34, 13% were 35-44, and 11,5% were under 18. Gender distribution among the participants was 85,9% male and 10,7% female.

Most used VR sets among the participants were Valve Index HMD (30,5%), Oculus Quest 2 (17,6%), HTC Vive (10,4%), and HP Reverb G2 (8.9%). Most popular genres participants reported were first person shooter (FPS)/shooter (34,3%), role playing game (10,1%), simulator (8,4%), and action (7,8%). Several participants wrote down specific games in the other option, which could indicate that participants found it difficult to attribute an experience to a single genre. These are summarized as "other" in the appendix (Appendix 2).

TABLE 5: Most significant sample characteristics, N = 347

Variable	Category	Frequency (Percent)
Age	Under 18	40 (11,5)
	18-24	144 (41,5)
	25-34	112 (32,3)
	35-44	45 (13,0)
Gender	Female	37 (10,7)
	Male	298 (85,9)
VR set used	Valve Index HMD	106 (30,5)
	Oculus Quest 2	61 (17,6)
	HTC Vive	36 (10,4)
	HP Reverb G2	31 (8,9)
Genre of experience	FPS/Shooter	119 (34,3)
	Role Playing Game	35 (10,1)
	Simulator	29 (8,4)
	Action	27 (7,8)

5.5 Data analysis

The data analysis began by exporting the data from Google Forms and inputting it into IBM SPSS Statistics Build 1.0.0.1447. The responses were examined and screened using Microsoft Excel and SPSS Statistics using the aforementioned procedures. As mentioned before, out of the 683 responses, 347 responses were included in the final dataset used in the examination. Then, the scale for question three (Q3) was reversed as it was the only reversed question in the questionnaire.

First, the internal reliability of the variables was tested by examining their Cronbach's alpha values. This resulted in the combination of six variables into three, and the removal of three questions. As a result, hypotheses H1abc, H3abc, and H5abc were discarded. Once the reliability of the variables was found sufficient, the variables were converted to mean variables and examined for normality using a Shapiro-Wilk test of normality. This resulted in the null hypothesis of normality being rejected. Then, the fit of the dataset for a factor analysis was examined using a Kaizer-Mayer-Olkin test as well as a Bartlett's test of sphericity.

Then, the model presented previously in figure 3 (Figure 3) was built in IBM SPSS Amos 26.0.0 Build 2233004. A confirmatory factor analysis (CFA) was performed, which showed that the original model showed poor validity and goodness-of-fit. Therefore, based on the results of the CFA and the structural model, the model had to be altered and the focus of the study changed. This led to hypotheses H4ab and H6ab being discarded, and three new hypotheses were introduced.

The final model consisted of a part of Lee's (2021) model, as well as connections between the variable interestingness and the main dimensions (PP, SP, INV) of the experience of immersion (immersive experience, IE), which was found when examining the original model. This model was examined with a CFA and then structural analysis using SPSS Amos. As the structural analysis could not account for the connections proposed by hypotheses H7-H9, a Spearman's correlation analysis was performed to examine these hypotheses.

6 RESULTS

This chapter presents the results of the quantitative study explained in the previous chapter (Chapter 5). First, the statistical analyses that were conducted are shown. Then, the results of the CFA for the original model are presented. Due to the poor validity and model fit these results showed, the model was altered, and the modification procedures done to the model are explained. Next, the new hypotheses and the final model were presented. Then, the results of the CFA of the final model are presented and was then converted to a structural model. The results of the analysis of the structural model are then presented. Finally, the results of a Spearman's correlation analysis are shown, and the results of the data analysis are summarized.

6.1 Statistical analyses

The reliability of the questions grouped to their proposed variables, or indicator variables, was tested using Cronbach's alpha. The purpose of this was to examine the internal consistency of the factors, which influences the reliability of the model (Metsämuuronen, 2002). This test revealed that the variables sensorimotor engagement, task/motor engagement, plausibility, and interactivity did not surpass the required 0,600 threshold (Metsämuuronen, 2002). This could be due to the small number of questions in each variable. Therefore, sensorimotor engagement and plausibility, task/motor engagement and interactivity as well as narrative engagement and interestingness were combined due to their hypothesized shared connections on the other variables in the model. Due to this, hypotheses H1abc, H3abc, and H5abc were discarded. Additionally, one question was removed from each construct to increase the Cronbach's alpha. The removed questions were Q3, Q4, and Q8, respectively (Appendix 1). One of these questions was the reversed question (Q3). This question asked if the participant experienced a delay between their actions and their effects in the VE. The data analysis showed that this question did not function as expected as it did not influence the scores of other variables and significantly lowered the Cronbach's alpha of the sensorimotor engagement variable. This could indicate that the question was not clear as participants did not know what the question was referring to. Alternatively, it could indicate that VR users with a lot of experience have grown accustomed to whatever delay there might be. Following these changes, the Cronbach's alphas ranged between 0,675 - 0,828, which indicates that all the factors are sufficiently internally reliable (Metsämuuronen, 2002). The Cronbach's alphas for each variable are presented in table 6 (Table 6).

TABLE 6: Cronbach's alpha

Variable	**Cronbach's alpha**
Sensorimotor engagement/Plausibility	0,675
Task/Motor engagement/Interactivity	0,717
Narrative engagement/Interestingness	0,815
Physical presence (PP)	0,785
Social/Self presence (SP)	0,828
Involvement (INV)	0,756

Next, the dataset was examined for normality using the Shapiro-Wilk test, where the null hypothesis states that the responses in the sample follow standard deviation (JMP). The results are presented in table 7 (Table 7), which indicated that all factors were highly significant, meaning that the null hypothesis of normality was rejected (JMP). This means the responses did not come from a normally distributed population (JMP). The test showed that the responses showed a bias towards the upper end of the 5-point Likert scale. This could indicate a bias in the sample group. Alternatively, this could also be explained by the immersive nature of VR technologies (e.g., Pallavicini & Pepe, 2019). This result is further examined in the limitations (Chapter 7.2). A list of all the questions and their statistical distributions are included in the appendix (Appendix 3).

TABLE 7: Shapiro-Wilk test of normality

Variable	**Statistic**	**Sig. (p-value)**
Sensorimotor engagement/Plausibility	**0,962**	**<0,001**
Task/Motor engagement/Interactivity	**0,949**	**<0,001**
Narrative engagement/Interestingness	**0,804**	**<0,001**
PP	**0,939**	**<0,001**
SP	**0,896**	**<0,001**
INV	**0,979**	**<0,001**

6.2 Structural equation modeling

As this study sought to examine the model presented by Lee (2021), structural equation modeling (SEM) was chosen as the method. SEM was chosen because this study sought to examine a theoretical model with a predefined structure (Devault, 2018). The data analysis in this thesis consisted of two parts: a confirmatory factor analysis (CFA) and an analysis of the structural model. The purpose of the CFA was to examine the reliability and validity of the variables, as well as examine the fit of the structure in the dataset compared to the proposed structure of Lee's (2021) model. The CFA was conducted using IBM SPSS Amos.

But first, to test the fit of the dataset for a factor analysis, a Kaizer-Mayer-Olkin (KMO) Test as well as a Bartlett's Test of Sphericity were conducted. The purpose of these tests was to examine if there are sufficient correlations in the dataset to conduct a factor analysis (IBM). The KMO value should be over 0,60, and the Bartlett's test should provide a significant p-value. These tests were performed using SPSS Statistics. The tests showed that the KMO value was 0,915, and the significance of the Bartlett's test was 0,000 for this dataset. These results indicated that the dataset can be used for a factor analysis (Kaiser & Rice, 1974; IBM).

6.2.1 Confirmatory factor analysis of the original model

The CFA began by creating a measurement model based on the conceptual model Lee (2021) proposed. The measurement model contained six latent variables and their indicator variables. Furthermore, SP was divided into two latent variables: social presence and self presence, which then functioned as indicator variables for a combined SP variable. In addition, one question measure of immersion (Q39) was also included. For the purpose of the CFA, the measurement model included covariances between all the factors.

Next, average variance extracted (AVE) values, factory loadings, and composite reliabilities were calculated to examine the construct validity and reliability of the model. These values for the original model are presented in table 8 (Table 8). The AVE value was used to examine convergent validity, meaning how close the indicator variables are coming together to determine their latent variables (Carlson & Herdman, 2012). AVE value greater than 0,5 indicates that the variables show acceptable convergent validity. In addition, the square root of the AVE value was used to examine discriminant validity, meaning how the latent variables in the model differ from one another. The square root of AVE must be higher than the correlations between the latent variable and other latent variables for them to be deemed acceptable (Fornell & Larcker, 1981). If both convergent validity and discriminant validity are deemed acceptable, the model can be said to have good construct validity (Ginty, 2013). Factory loadings indicate the correlations between a latent factor and its indicator factors. In essence, it indicates how much of the variance in the latent factor each indicator factor explains. Finally, composite reliability indicates construct reliability, meaning how closely grouped together the indicator variables of a latent factor are. The composite reliability values should be over 0,6 (Bacon, Sauer & Young, 1995).

TABLE 8: Reliability, validity, and loadings of the original model

Latent variable	**AVE**	**Square root of AVE**	**Composite reliability**	**Indicator variable**	**Loadings**
SP	0,457493	0,676382	0,615175	Social Presence	0,504
				Self Presence	0,813
Task/Motor Engagement/Interactivity	0,364697	0,603901	0,738484	Q5	0,639
				Q6	0,665
				Q13	0,523
				Q14	0,677
				Q15	0,491
INV	0,376332	0,613459	0,830465	Q38	0,671
				Q37	0,744
				Q36	0,55
				Q35	0,566
				Q34	0,505
Narrative Engagement/Interestingness	0,482209	0,694413	0,830465	Q7	0,594
				Q8	0,73
				Q16	0,72
				Q17	0,67
				Q18	0,747
PP	0,478857	0,691995	0,830902	Q19	0,606
				Q20	0,756
				Q21	0,758
				Q22	0,762
				Q23	0,548
Social Presence	0,621316	0,788236	0,829525	Q24	0,856
				Q25	0,841
				Q26	0,865
				Q27	0,803
				Q28	0,523
Self Presence	0,394083	0,62776	0,828843	Q29	0,622
				Q30	0,704
				Q31	0,591
				Q32	0,425
				Q33	0,747
Sensorimotor Engagement/Plausibility	0,303683	0,551074	0,831774	Q1	0,596
				Q2	0,529
				Q10	0,634

				Q11 Q12	0,501 0,48

As the table indicates, the composite reliabilities of the latent variables were sufficient, as well as the Cronbach's alphas as indicated previously (Table 6). However, all latent variables except social presence did not reach the sufficient 0,5 AVE value to show appropriate convergent validity. Furthermore, the test for discriminant validity showed that PP was the only variable that had a sufficient square root of AVE value. The correlations between the latent variables are presented in table 9 (Table 9). These findings indicate that with this dataset, the model shows poor construct validity.

TABLE 9: Correlations between latent variables in original CFA model

Correlations	**Value**
SP ←→ Sensorimotor engagement/plausibility	0,772
Task/motor engagement/interactivity ←→ SP	0,438
Task/motor engagement/interactivity ←→ INV	0,645
INV ←→ Narrative engagement/interestingness	0,611
Narrative engagement/interestingness ←→ PP	0,536
PP ←→ Sensorimotor engagement/plausibility	0,784
INV ←→ PP	0,715
INV ←→ SP	0,831
PP ←→ SP	0,878
INV ←→ Sensorimotor engagement/plausibility	0,683
Task/motor engagement/interactivity ←→ PP	0,566
Narrative engagement/interestingness ←→ SP	0,450
Narrative engagement/interestingness ←→ Sensorimotor engagement/plausibility	0,626
Task/motor engagement/interactivity ←→ Sensorimotor engagement/plausibility	0,716
Task/motor engagement/interactivity ←→ Narrative engagement/interestingness	0,934
PP ←→ IE	0,668
INV ←→ IE	0,562
SP ←→ IE	0,682
Sensorimotor engagement/plausibility ←→ IE	0,640
Task/motor engagement/interactivity ←→ IE	0,353
Narrative engagement/interestingness ←→ IE	0,353

The problems can be further seen by examining the goodness-of-fit indices of the model, which are presented in table 10 (Table 10). The goodness-of-fit indices indicate the relationship between the connections in the dataset and the connections proposed by the model (Alavi et al., 2020). The chi-square goodness-of fit-test showed that the chi-square value was 1363,511 with 572 degrees of freedom (DF), and its associated p-value, which indicates its significance, was less than 0,001. Therefore, the null hypothesis of a perfect fit between the dataset and the model was rejected (Alavi et al., 2020). However, Alavi et al.

(2020) stated that the chi-square statistic should not be used as the sole determinant for model fit, as it is sensitive to sample size. Therefore, comparative fit index (CFI), normed fit index (NFI), Tucker-Lewis index (TLI), and root mean square error of approximation (RMSEA) are also presented (Table 10).

TABLE 10: Goodness-of-fit tests for the CFA version of the original model

Degrees of freedom	**Goodness-of-fit index**	**Value**
572	Chi-square	1363,511; p=0,000
	CFI	0,850
	NFI	0,770
	TLI	0,835
	RMSEA	0,063

CFI ranges between 0 and 1. High values indicate a good fit, and a CFI value greater than 0,95 is considered an acceptable fit (Cangur & Ercan, 2015). The same principle goes for both NFI and TFI, higher values indicate a good fit. Values between 0,9 and 0,95 suggest an acceptable fit for NFI (Bentler & Bonett, 1980), and TLI value of 0,95 is deemed an acceptable fit (Cangur & Ercan, 2015). Finally, if the RMSEA value is smaller than 0,05, it suggests that the model is a good fit for the underlying data. Alternatively, a value between 0,05 and 0,08 still suggests a reasonable fit (Cangur & Ercan, 2015). While these values suggest that the model is not far from a good fit, for example RMSEA is still within the bounds of a reasonable fit, the fact that the model shows poor construct validity makes it unfit for further examination. This could indicate that there are problems with the model Lee (2021) proposed. Alternatively, it could indicate that the questions chosen for the questionnaire were a poor fit. This will be further discussed in the discussion of this thesis (Chapter 7).

6.2.2 Model modification procedures

The measurement model was then converted into a structural model to further examine the reasons why it did not work as expected. This meant that the covariances between the latent variables were removed and replaced by the connection shown in figure 3 (Figure 3), which was presented in the hypotheses chapter (Chapter 4.3.2). It is worth noting, however, that SEM does not allow to account for the covariances suggested by H7-H9. The examination of this model revealed that the standardized residual covariances between the indicator variables were high. These values indicate the points of misfit within the model (Maydeu-Olivares & Shi, 2017). Therefore, a standardized root mean square residual (SRMR) was calculated. This value indicates the standardized difference between correlations in the dataset and the correlations the model suggests (Hu & Bentler, 1999). The SRMR value for the structural model was 0,1858, while a value less than 0,08 suggests a good fit (Hu & Bentler, 1999). While the strong correlations between the variables PP, SP, and INV were expected due to hypotheses H7-H9, the correlations between the combined variables were not expected.

A Spearman's correlation matrix of all the questions is included in the appendix (Appendix 4). The analysis was done using IBM SPSS Statistics. Spearman's correlation analysis was chosen as the hypothesis of normality was rejected, and Pearson's correlation analysis requires a mostly standard deviation among the responses (Artusi, Verderio & Marubini, 2002). The matrix (Appendix 4) shows that the majority the indicator variables are significantly correlated with one another. This was partially expected as certain variables were expected to correlate with one another, and because the purpose of the model was to capture many elements that lead to one central concept. However, as indicated by the results of the CFA, perhaps the variables were not sufficiently differentiated from one another as indicated by the poor construct validity. Future examinations into the model should note the similarities between the variables and set clear boundaries between them.

Therefore, the model had to be modified to meet the goodness-of-fit criteria as well as to provide sufficient construct validity. First, further testing showed that the variables sensorimotor engagement/plausibility and task/motor engagement/interactivity could not achieve sufficient reliability and validity regardless of changes done to the indicator variables while keeping their core concepts. Therefore, they were removed. This resulted in hypotheses H4ab and H6ab being discarded. Then, a number of indicator variables from each remaining latent variable were removed according to their factory loadings and standardized residual covariances, while keeping in mind the theoretical background of Lee's (2021) hypotheses. Indicator variables that showed a smaller loading towards their latent variables as well as indicator variables that showed a high covariance for variables in other latent variables were removed. Furthermore, SP was separated into social presence and self presence variables as their combination had a notable negative effect on the fit of the model. Out of the 38 original questions attributed to the latent variables, only 14 questions were kept.

The remaining variables were PP, INV, social presence, self presence, and narrative engagement/interestingness. However, the removal of indicator variables led to narrative engagement/interestingness variable losing its indicators relating to the narrative engagement variable. Therefore, the variable was renamed as the interestingness variable and hypothesis H2ab was discarded. It is worth noting that while the rest of the variables kept their core concept, the removal of questions led to them not covering their respective concepts as fully as in the original model. Future research should do more extensive testing to create and validate more comprehensive scales for Lee's (2021) model in the future.

6.3 Structure and hypotheses of the final model

Because of the aforementioned changes, examining the full model was no longer possible. However, as mentioned before, the narrative engagement/interestingness variable showed correlations between all the variables instead of just PP and INV as hypotheses H1abc and H2ab stated. Therefore, the final model sought to examine the influence of the interestingness variable on PP, INV, social presence, and self presence, as well as their influence on the experience of immersion. Therefore, hypothesis H2ab was discarded and replaced by an additional hypothesis derived from the examination of the original model. The hypothesis suggests that:

- H11abcd: Interestingness has a positive effect on INV (H11a), PP (H11b), self presence (H11c), and social presence (H11d).

- H12: Interestingness has a positive effect on IE.

In addition, as the variables social presence and self presence were separated, this allowed for the testing of a hypothesis Lee (2021) briefly mentioned in his article. He hypothesized that social interactions should positively influence a user's sense of self presence (Lee, 2021). Therefore, hypothesis H12 states that:

- H13: Social presence has a positive effect on self presence.

The structure of this model, the remaining hypotheses that were examined, and the remaining indicator variables are presented in figure 4 (Figure 4).

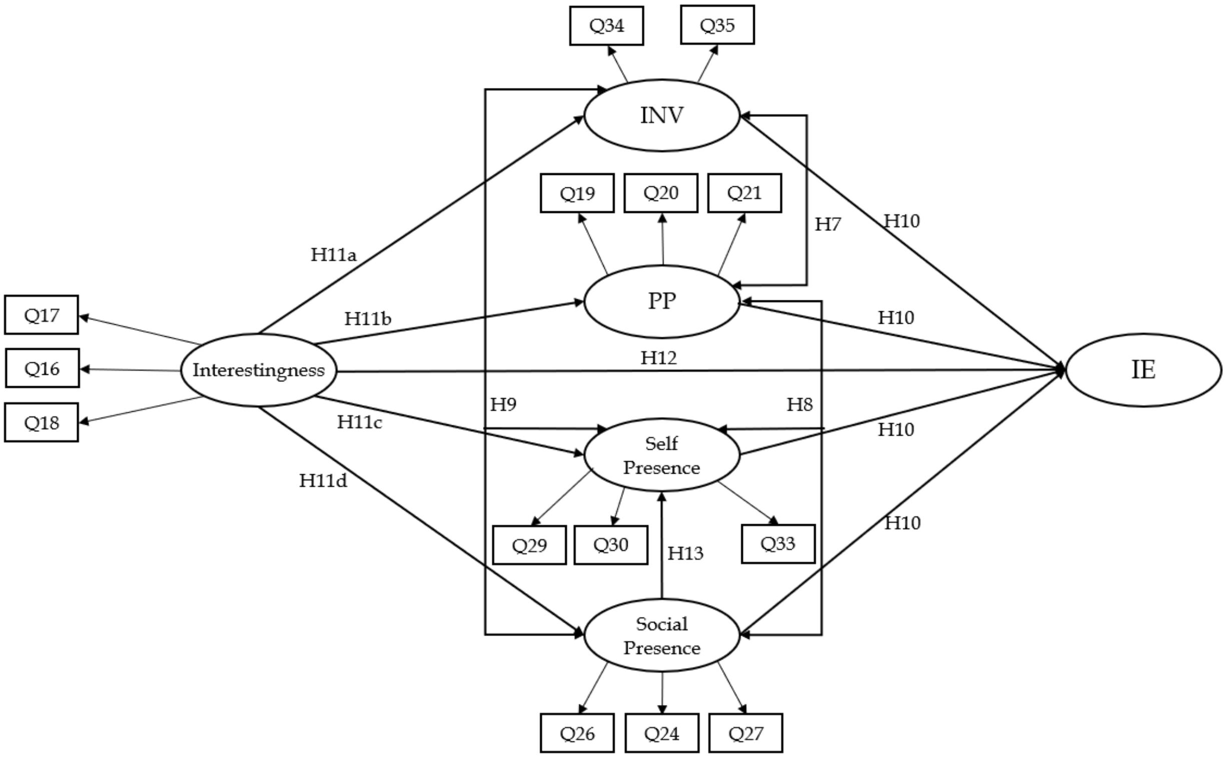

FIGURE 4: Structure and hypotheses of the final model.

6.3.1 Confirmatory factor analysis of the final model

Again, a CFA was performed to examine the validity, reliability, and fit of this model and its variables. The measurement model was created in IBM SPSS Amos with the previously explained changed variables, and covariances between them. Then, AVE values, factory loadings, Cronbach's alphas, and composite reliabilities were calculated. The results are presented in table 11 (Table 11).

TABLE 11: Reliability, validity, and loadings of the final model

Latent variable	**AVE**	**Square root of AVE**	**Cronbach 's alpha**	**Composite reliability**	**Indicator variable**	**Loadings**
Interestingness	0,515766	0,718169	0,757	0,761387196	Q18 Q16 Q17	0,755 0,693 0,705
INV	0,563485	0,750656	0,708	0,718836894	Q34 Q35	0,673 0,821
Social Presence	0,716166	0,846266	0,882	0,883161884	Q26 Q24 Q27	0,885 0,845 0,807
Self Presence	0,506021	0,711351	0,752	0,753783371	Q29 Q30	0,649 0,731

					Q33	0,750
PP	0,540273	0,735033	0,765	0,777135558	Q21	0,763
					Q20	0,805
					Q19	0,625

As the table shows, the composite reliabilities as well as Cronbach's alphas of the latent variables were all over the required 0,600 threshold (Bacon et al., 1995; Metsämuuronen, 2002). All latent variables showed both acceptable convergent validity (AVE > 0,5) and discriminant validity, since the highest correlations did not reach above 0,7. The correlations between the latent variables are presented in table 12 (Table 12). These findings indicate that this model has acceptable reliability and construct validity.

TABLE 12: Correlations between the latent variables in the final CFA model

Correlations	**Value**
Interestingness ←→ Social presence	0,318
Interestingness ←→ Self presence	0,194
Interestingness ←→ INV	0,294
Interestingness ←→ IE	0,361
INV ←→ Self presence	0,469
INV ←→ Social presence	0,300
INV ←→ IE	0,285
PP ←→ Interestingness	0,576
PP ←→ INV	0,383
PP ←→ Self presence	0,550
PP ←→ Social presence	0,417
PP ←→ IE	0,616
Social presence ←→ Self presence	0,384
Social presence ←→ IE	0,310
Self presence ←→ IE	0,549

The goodness-of-fit indices for this model are presented in table 13 (Table 13). The table shows that the chi-square goodness-of fit-test was still significant. Therefore, the null hypothesis of a perfect fit between the dataset and the model was rejected (Alavi et al., 2020). However, as Alavi et al. (2020) stated, it should not be used as the sole determinant of model fit. The rest of the examined goodness-of-fit indices indicated that the model showed a good fit between the data and the model (Bentler & Bonett, 1980; Cangur & Ercan, 2015; Hu & Bentler, 1999).

TABLE 13: Goodness-of-fit tests for the CFA version of the final model

Degrees of freedom	**Goodness-of-fit index**	**Value**
76	Chi-square	134,979; p=0,000
	CFI	0,970
	NFI	0,935
	TLI	0,958

	RMSEA	0,047
	SRMR	0,0392

6.3.2 Structural equation model of the final model

As the model and its variables were deemed acceptable in terms of reliability, construct validity, and fit, it was converted to a structural model. This meant that the covariances between the variables were removed and the connections between the variables suggested by the original model presented in the hypotheses chapter (Figure 3), as well as the new hypotheses were added (Figure 4). This model and the results of the analysis of the structural model are summarized in figure 5 (Figure 5). However, it is important to note that the analysis did not allow to examine covariances or correlations between variables that are determined or influenced by other variables. Therefore, analysis of the structural model could not examine hypotheses H7-H9.

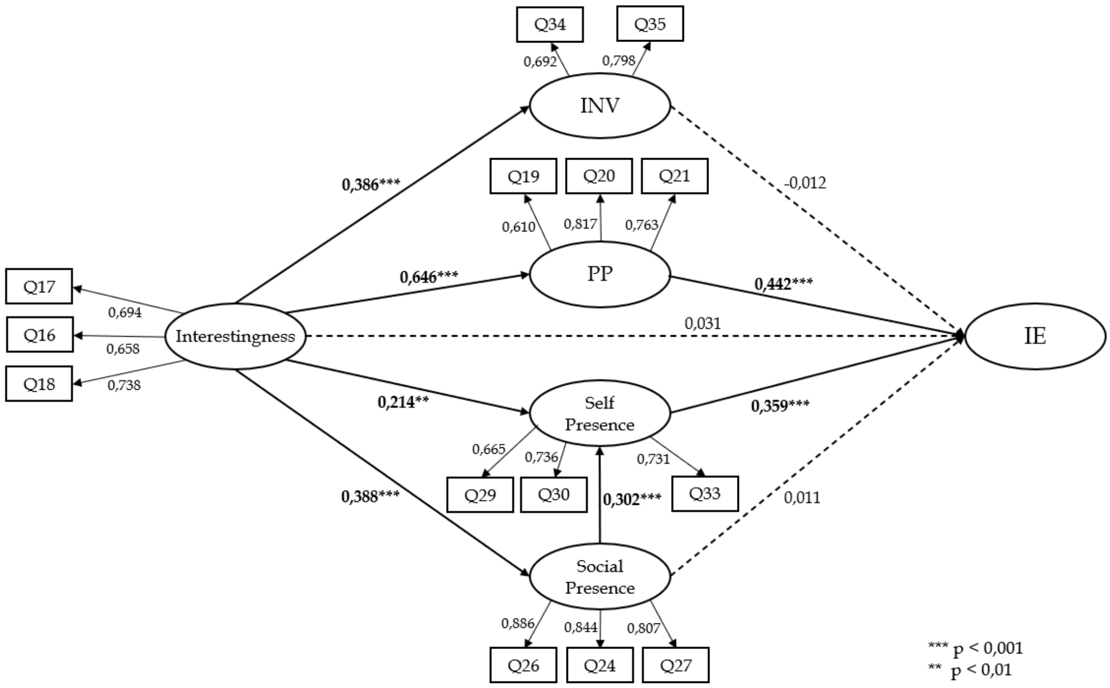

FIGURE 5: Final structural model and results

Hypotheses that were accepted as of this dataset are presented with a continuous line, and the dotted lines represent hypotheses that were not accepted. Beta (standardized) coefficients are displayed next to the lines, and the asterisks present the associated p-value of each relationship. The beta coefficient indicates the strength of the relationship between the variables (Metsämuuronen, 2008). The t-value associated with the regression coefficient, in addition with its significance (p-value), indicates its reliability. If the t-value is greater than two (t>2) and the p-value is smaller than 0,05 (p<0,05), the regression coefficient is reliable (Metsämuuronen, 2008). The t-values and p-values are presented in table 14 (Table 14). As the p-values and t-values indicate, all the accepted hypotheses were reliable (Metsämuuronen, 2008). As the figure shows, the regression coefficients for the connections between interestingness and the main dimensions of IE were significantly different from zero and reliable. In addition, the regression coefficient of the connection between social presence and self presence was also significantly different from zero and reliable. Therefore, hypotheses H11abcd and H13 could be accepted as of this dataset. Hypothesis H12 was not supported, as the regression coefficient for the connection between interestingness and IE was not significantly different from zero. Finally, hypothesis H10 was partially supported, as the regression coefficients of the connections between PP and self presence were significantly different from zero and reliable, however, the regression coefficients of the connections between INV and IE, and social presence and IE, were not. Furthermore, the R^2-value for IE was 0,419, which indicates that INV, PP, social presence, and self presence account for 41,9% of the variance in IE.

TABLE 14: The t-values and p-values of the relationships in the final model

Relationship	**t-value**	**p-value**
Interestingness → INV	4,368	**<0,001**
Interestingness → PP	8,395	**<0,001**
Interestingness → Self Presence	2,831	**0,005**
Interestingness → Social Presence	5,874	**<0,001**
INV → IE	-0,206	0,837
PP → IE	5,671	**<0,001**
Self Presence → IE	5,689	**<0,001**
Social Presence → IE	0,191	0,848
Interestingness → IE	0,342	0,732
Social Presence → Self Presence	4,196	**<0,001**

In addition, the goodness-of-fit indices were examined for the structural model, and they are presented in table 15 (Table 15). As the table shows, the goodness-of-fit values were no longer fully within the range of an acceptable fit (Bentler & Bonett, 1980; Cangur & Ercan, 2015; Hu & Bentler, 1999). However, they were close. Furthermore, this was suggested to be caused by the correlations between INV, PP, and social presence and self presence variables, as stated in hypotheses H7-H9. Hypotheses H7-H9 stated that PP and INV have a positive effect to each other (H7), PP and SP have a positive effect to each other (H8), and INV and SP have a positive effect on each other (H9). Note that SP includes both social and self presence variables. However, as mentioned before, the analysis of the structural model did not allow to account for the correlations or covariances between the variables.

TABLE 15: Goodness-of-fit indices for the final structural model

Degrees of freedom	Goodness-of-fit index	Value
81	Chi-square	229,994; p=0,000
	CFI	0,924
	NFI	0,889
	TLI	0,901
	RMSEA	0,073
	SRMR	0,0910

Therefore, the variables from the structural model were converted to mean variables, and a Spearman's correlation analysis was performed using IBM SPSS Statistics to test these hypotheses. A correlation coefficient was chosen due to the two directional connections between the factors (Tompkins, 1992), and Spearman's correlation analysis was chosen due to the null hypothesis of normality being rejected (Artusi et al., 2002). The results of the Spearman's correlation analysis are presented in table 16 (Table 16).

TABLE 16: Spearman's correlation analysis H7-H9

	PP	**INV**	**Social presence**	**Self presence**
PP	1,000	**0,304***	**0,427***	**0,443***
INV	**0,304***	1,000	**0,313***	**0,349***
Social presence	**0,427***	**0,313***	1,000	**0,339***
Self presence	**0,443***	**0,349***	**0,339***	1,000

*** P= <0,001 (2-tailed).

As can be seen from the table, all the correlation coefficients were significantly different from zero, which indicates that hypotheses H7, H8, and H9 can be accepted as of this dataset. However, examining the direction of the connections between the variables is outside the scope for this thesis and should be examined in future research.

These results present evidence to the suggestion that the discrepancy between the goodness-of-fit values of the CFA model and the structural model could be caused by the correlations between these variables. However, examining if there are other factors that influence the discrepancy between the goodness-of-fit values is outside of the scope of this thesis.

The results presented in figure 5 (Figure 5) showed that hypothesis H11abcd was accepted. This means that unlike Lee (2021) hypothesized, interestingness has a positive effect on INV, PP, social presence, and self presence. However, as Lee (2021) suggested, hypothesis H12 was not supported, meaning that interestingness does not have a direct effect on IE. The figure (Figure 5) shows that hypothesis H13 was also accepted, meaning that social presence has a significant positive effect on self presence. Hypotheses H7, H8, and H9 were also accepted as of this dataset as showed in table 16 (Table 16). However, hypothesis H10 was only partially supported by this dataset. While PP and self presence had a significant positive connection to IE, INV and social presence did not. As mentioned previously, the R^2-value for IE was 0,419, meaning that INV, PP, social presence, and self presence account for 41,9% of the variance in IE. These results are further examined in the next chapter (Chapter 7), as well as the limitations of this study.

7 Discussion

Examining the experience of immersion in the context of VR is important because it is commonly understood that the higher level of immersion a user feels, the more satisfying and enjoyable the experience is (e.g., Ermi & Mäyrä, 2005; Pallavicini et al., 2019). This, accompanied with the rapidly growing interest in VR technologies of consumers, researchers, and business enterprises (e.g., Angelov et al., 2020; Mütterlein & Hess, 2017) and its' expected impact in numerous fields (Slater & Sanchez-Vives, 2016; Hudson et al., 2018), make examining the experience of immersion in VR an important topic of research. The research question of this thesis was:

- How is immersion achieved with modern virtual reality technologies?

The literature review done in this thesis examined prior literature relating to the experience of immersion, presented several categories of factors that influence it, and related them to the conceptual model of the experience of immersion presented by Lee (2021). As the scope of the literature review was broader than the scope of the empirical study, these factors could not be examined in this study. However, they do provide a number of research topics for future studies, as well as highlight important aspects related to VR use that should be considered in addition to the influencing factors Lee (2021) presented in his model. Furthermore, while examining these factors is important, Lee's (2021) model had not been empirically examined. Therefore, the empirical study done in this thesis sought take the first steps into empirically examining Lee's (2021) conceptual model. Lee's (2021) model presents the experience of immersion as a multidimensional construct consisting of physical presence (PP), social/self presence (SP) and involvement (INV). In addition, Lee (2021) hypothesized that the initial stage of PP and INV is narrative engagement, the initial stage of PP and SP is sensorimotor engagement, and the initial stage of SP and INV is task/motor engagement (Lee, 2021). Furthermore, PP and INV are influenced by interestingness of the content, PP and SP are influenced by plausibility of the virtual environment (VE) stimulus, and SP and INV are influenced by interactivity of the content (Lee, 2021).

This chapter focuses on examining the results of the empirical study conducted in this thesis and compares them to findings in prior research. Furthermore, it considers the reliability and validity of the results, as well as their limitations, and presents research topics for future research. While examining the factors influencing the experience of immersion found in the literature review would have been interesting and important, the scope of the thesis could not allow for that. Therefore, the empirical study focused solely on examining the conceptual model presented by Lee (2021). As this model had not been previously empirically examined, this thesis took the important first steps in to examining the model. Examining this model is crucial for examining the experience of immersion in the context of VR, as it bridges the gap between research on the experience of immersion, presence, and VR research, which have long been plagued with unclear and differing definitions for each concept (e.g., Cairns et al., 2014; Mütterlein, 2018). In addition, it suggests a relationship between the concepts of presence and immersion, which has been long debated (e.g., Lee, 2021).

Examination of the original model showed it to be problematic with this dataset. The confirmatory factor analysis (CFA) indicated that its variables showed poor construct validity, and the goodness-of-fit indices showed it to have a poor fit with this dataset. This could indicate that there are problems with the model Lee (2021) proposed. However, the questionnaire constructed in this thesis was limited in length and the scope of this thesis did not allow thorough testing of the measurement scales. Furthermore, Lee's (2021) descriptions of the engagement variables (sensorimotor engagement, narrative engagement, and task/motor engagement) as well as the factors related to content and system (plausibility, interactivity, and interestingness) were simplistic. These, in addition to the fact that there were no pre-existing scales for these variables, led to these scales being developed and tested for the first time during this study. Therefore, it is suggested here that the poor construct validity was likely due to the previously untested and unvalidated scales. Future research should focus on developing and carefully testing more comprehensive scales for the variables in Lee's (2021) model. As noted before, future studies should set clear boundaries for each variable to improve the validity of the constructs.

Because of this, changes had to be made to the variables, and the focus of the data analysis had to be changed, since examining the full model was no longer possible as was originally intended. The changes done to the model resulted in hypotheses H1abc, H2ab, H3abc, H4ab, H5abc, and H6ab to be discarded. However, with some modifications, the examination of the final model (Figure 4) presented in the previous chapter (Chapter 6) as well as the shortcomings of the original model did result in some valuable findings.

Most notably, the changed focus of the study saw the introduction of hypotheses H11abcd, H12, and H13. The results of the analysis on the final structural model showed that hypotheses H11abcd and H13 were accepted. H11abcd stated that interestingness, or the user's interest towards the content they are experiencing, positively effects INV, PP, social presence, and self presence. Though Lee (2021) hypothesized that interestingness would influence PP and INV, the results of this study suggest that interestingness influences all the dimensions of IE. While the effect of interest has been found and suggested on PP and INV in prior research (e.g., Nilsson et al., 2016; Suh & Prophet, 2018; Slater, 2003), its effect to social presence and self presence has not been well studied. Furthermore, there have been some conflicting views regarding the direct influence of interest on PP (Nilsson et al., 2016; Slater, 2003).

Hypothesis H12 was not supported. This suggests that, as Lee (2021) hypothesized, interestingness alone does not have a direct effect on the experience of immersion. This finding is interesting as interestingness has been attributed as an important factor that is required for immersion to be achieved (Arsenault, 2005; Brown & Cairns, 2004). However, it is worth noting that these authors defined the experience of immersion from an INV focused perspective (Arsenault, 2005; Brown & Cairns, 2004; Lee, 2021).

As Lee (2021) hypothesized, the results supported hypothesis H13, which stated that social presence positively effects self presence. Lee (2021) proposed that users might feel more connected to their virtual self through social interactions with other people in the VE. While the connection of social presence to presence has been suggested (Shin, 2018; Skarbez et al., 2017; Bulu, 2012), the relationship between social presence and self presence has not been well studied and requires further examination in future studies.

In addition to the hypotheses introduced in the previous chapter (Chapter 6), hypotheses H7, H8, H9, and H10 were also able to be examined. As the results of the Spearman's correlation analysis (Table 16) showed, hypotheses H7, H8, and H9 were all supported as of this dataset. Hypothesis H7 stated that PP and INV influence each other. This connection has been well documented in prior research (Brown & Cairns, 2004; Ermi & Mäyrä, 2005; Hou et al., 2012; Witmer & Singer, 1998). Hypothesis H8 proposed that PP and SP influence each other, meaning that both social presence and self presence influence PP, and PP influences both social and self presence. This result was also supported by prior research (Bulu, 2012; Oh, Bailenson & Welch, 2018; Shin, 2018; Skarbez et al., 2017). H9 presented that social presence and self presence, and INV influence each other. These connections have not been widely researched, however there is some evidence for them in prior research (Gajadhar, de Kort & Ijsselsteijn, 2009; Hou et al., 2012; Waltemate et al., 2018).

Finally, H10 was partially supported. The results indicated that PP and self presence had a significant positive connection to IE, with PP having the most significant influence. These findings are supported by prior research (e.g., Cairns et al., 2014; Mütterlein, 2018). However, the results showed that neither INV nor social presence had a significant effect on IE. The lack of connection between INV and IE is interesting, as the two questions in the INV variable (Q34, Q35) focused on a state of deep focus during which the user is completely concentrated on the stimulus of the VE and "lose" themselves in it, which is often attributed as a key feature of the experience of immersion (e.g., Agrawal et al., 2020; Jennett et al., 2008; Cairns et al., 2014).

In addition, the results of this study suggest that social presence does not have a significant connection to IE. There have been conflicting findings on the relationship between social presence, social interaction, and IE (e.g., Cairns et al., 2014; Hudson et al., 2018). Some studies have suggested that social interaction and social presence can increase the experience of immersion (e.g., Cairns et al., 2014; Hudson et al., 2018), while others have suggested that social interaction distracts the user from the experience, thus interrupting immersion (e.g., Ermi & Mäyrä, 2005). It is worth noting that the question relating to social interaction (Q27) in the social presence variable asked whether users felt a high level of social interaction. However, the studies reported by Hudson et al. (2018) and referenced by Cairns et al. (2014) found that a low level of social interaction led to a higher level of immersion. Future studies should examine if the level of social interaction influences the experience of immersion differently and examine the effect of social interaction and social presence on IE in the context of VR further.

The results of this study provide further evidence toward the claim that there is a relationship between presence and IE (e.g., Cairns et al., 2014; Tussyadiah, Wang, Jung & tom Dieck, 2018) as the results showed that PP had the strongest connection to IE. In addition, the study provides further evidence towards the claim that self presence is positively related to IE, and while social presence did not have a positive effect on IE, it did not have a negative effect on it either.

Furthermore, the results showed that unlike Lee (2021) proposed, users' interest toward the scenario, the type of experience, and tasks and activities they performed in the VE have a positive effect on all the dimensions of IE. Therefore, it is suggested here that future examinations of the model should investigate the influence of the interestingness variable on all the dimensions. However, as the final model only examined a part of Lee's (2021) model, it is worth noting that these results might not be the same when the full model is considered, or when the correlations between the main dimensions are considered.

In addition, as mentioned previously, the results found that interestingness does not directly affect IE, as Lee (2021) suggested. As mentioned before, interest towards the content is often attributed as a key component to achieving immersion (e.g., Brown & Cairns, 2004), which makes this finding interesting. One possible explanation for this is that the measure of IE used in this study was simple. Future studies should re-examine this result using a more substantial measure for IE. However, as mentioned before, for example, the study done by Brown and Cairns (2004) used a definition of IE that was primarily focused on INV, and this connection was found in the study.

Why INV was not found significant, this could possibly be explained in a few ways. Firstly, Lee (2021) described INV as a more general concept in the model and did not provide as clear of a definition as the other main dimensions of IE (PP, social presence, self presence). It is possible that the interpretation of

INV the author utilized in the questionnaire was not adequate to what Lee (2021) intended. Another set of questions for INV or more questions in general, may lead to a different result. Secondly, the two questions included in the final model focused on subjective experiences that might be difficult to recall. Even more so over a period of time, as the participants answered the questionnaire based on an experience that happened at most within seven days (Weech et al., 2019). Repeating this study in a laboratory setting where the participants can answer the questionnaire immediately after the experience might provide more accurate results. Thirdly, as Lee (2021) stated, PP, SP, and INV influence each other and collectively contribute towards the experience of immersion. However, he also added that immersion does not require all of PP, SP, and INV to occur together (Lee, 2021). Lee (2021) hypothesized that how much each of them contributes is dependent on the type of experience. While examining this weighting of these variables is outside the scope of this thesis, it is possible that the type of experiences the participants reported were less focused on eliciting INV. In addition, due to the heterogenous sample of genres of experiences users reported, examining this would not be possible with this dataset. Future studies should focus on a single genre or collect a larger dataset to properly examine these weightings. Furthermore, as mentioned previously, there have been conflicting findings on the impact of social interaction on immersion, and more specifically the aspects of immersion related to the definition of INV used in this study (Cairns et al., 2014; Hudson et al., 2018). As the dataset consisted of users whose experiences included other people, this explanation is worth examining in future studies. However, this study considered both human controlled players and computer-controlled agents as social entities in the VE. Future studies could examine if this distinction would make a difference in the social presence scores and its influence on IE.

Analysis of the structural model showed that PP, SP, and INV explained 41,9% of the variance of immersive experience. While this is quite high, it also means that 58,1% of IE is explained through other factors. However, this result was expected since the model examined only a portion of Lee's (2021) model and did not take the correlations found by H7-H9 into account. Perhaps examining the full model with a more substantial questionnaire while taking the correlations between the variables into account could improve its explanatory capabilities. In addition, it is possible that including more factors presented in chapter 4.2 could improve its ability to explain the variance in IE.

7.1 Reliability and validity of the study

An effort was made to improve the reliability of the results by carefully screening the dataset before conducting the data analysis, and the results were examined for reliability using statistical methods during the analysis. The data was carefully screened for nonvariant responses, and an effort was made to ensure that participants belonged to the group the survey was targeting. During the data analysis, care was taken to examine the reliability and validity of the models and the latent variables. As the validity of the original model was found not sufficient, the results were carefully examined and the new model was deliberately constructed with close attention to its reliability, validity, and fit. While the final structural model did not exhibit a good fit, it was close, and possible reasons for this was presented and evidence towards these claims were given.

Good scientific practices were followed when designing the study in an effort to improve the validity of the results. The hypotheses were formed by carefully examining Lee's (2021) article and the references he employed. The questionnaire form was then constructed by examining 21 previously validated questionnaires relating to the variables, and the questions were carefully chosen and crafted to fit the hypotheses. Before publishing, the questionnaire was presented to the advisor for this thesis, an additional University of Jyväskylä faculty member, and it was tested using two participants to improve the clarity and understandability of the questions.

7.2 Limitations and future research

There are several limitations with this thesis. Firstly, there were several issues and limitations with the literature review conducted. The topic chosen for this thesis got significantly expanded and more complicated due to the difficulties surrounding the definitions of immersion, presence, and their relationship. As mentioned previously, the concepts of immersion and presence are both complicated and both have been defined in numerous ways over a number of fields (e.g., Jennett et al., 2008; Nilsson et al., 2016; Weech et al., 2019). These numerous definitions found in literature for both concepts makes examining them and their relationship challenging. This in combination with the restrictions on scope, led to the fact that there several topics covered in the literature review could not be examined as extensively as would have been preferred. Finally, as the literature review conducted in this study was not systematic, replicating the literature review presented in this thesis would be challenging, which impacts the reliability of the thesis.

In addition, the definitions of immersion and presence, and their relationship are still heavily debated (e.g., Agrawal et al., 2020; Cairns et al., 2014). While this study provides further empirical evidence that presence and immersion are related, future research should focus on unifying and cementing their definitions across fields of research and exploring their relationship further.

While several categories of factors influencing the experience of immersion in the context of VR were presented in chapter 4, limitations in scope forced the empirical study to focus on examining the base form of the conceptual model that Lee (2021) proposed. It is up to future research to examine the influences these factors have on the experience of immersion. Furthermore, the connections between the categories of factors and Lee's (2021) model presented in chapter 4.3 also require empirical testing.

The method chosen for the empirical study also presented several limitations and problems. Why the survey method was chosen was explained in chapter 5.2, however, this method and this topic for the empirical study was not planned from the start. The difficulties related to cost of equipment, physical labor required, and more importantly several concerns related to the ongoing COVID-19 pandemic resulted in the topic for the empirical study to be reconsidered, as conducting a controlled experiment was not feasible in the scope of this thesis. While the study conducted here yielded some valuable findings, future research should re-examine Lee's (2021) model in a controlled setting and compare the results.

As the survey was conducted over the internet, it was important that the questionnaire form was not too long. This presented problems as the concepts it attempted to examine were complex. For example, a commonly used presence questionnaire (PQ) by Witmer and Singer (1998) has 32 questions just to examine the experience of (physical) presence. Condensing these concepts to measures of just five to three questions presented a significant challenge while constructing the study and could potentially influence the results. Furthermore, due to limitations in the length of the questionnaire, only one reversed question (Q3) was included to help in screening it for unreliable and inattentive responses. However, as this question (Q3) was found ineffective, it is possible that there is unreliable data in the dataset. The data was carefully screened for invariant responses; however, this only exposes the most blatantly inattentive participants. Future studies should include more reversed and attention trap questions to improve the reliability of the dataset.

Due to the method chosen, various VR sets were reported by participants. As mentioned earlier, the technical specifications of the VR set in use have an influence on the experience of immersion. Future research should test if there is a difference in the results if for example only a single VR set is considered. In addition, various genres of experiences were also reported. Lee (2021) hypothesized that the content being experienced influences how much PP, SP, and INV influence the experience of immersion. For example, some experiences or genres of experiences do not invoke social presence due to the lack of other characters, however, they create the experience of immersion by providing high levels of PP and INV (Lee, 2021). However, examining the weighting of the types of content was outside the scope of this thesis. Future research should examine the concept of the overall level of immersive experience (OLIE) Lee (2021) presented in his article and examine the weightings of different genres by redoing the study and, for example, targeting participants that all experienced the same content or content from a single genre.

The survey was targeted towards VR owners with moderate to high levels of experience. This means that generalizability of the results presented in this study is limited. Future studies should examine if the results are impacted if the responses are collected from participants with alternate levels of experience in using VR sets. In addition, a majority of the responses were reported based on VR games. This was to be expected since, at this time, the main use for

VR among private consumers is focused on entertainment (Mehrfard et al., 2019). However, this means that the results are not generalizable outside the context of VR games. Nevertheless, Lee's (2021) model and the questionnaire constructed in this thesis were not designed to be limited to just games. As other VR applications become more relevant, future research should examine if Lee's (2021) model is applicable in the context of VR software outside of entertainment.

While subjective measures for examining the variables in the model have been used successfully in the past (e.g., Jennett et al., 2008; Baños et al., 2000; Schubert, Friedmann & Regenbrecht, 2001; Witmer & Singer, 1998; Suh & Prophet, 2018), they have also received some criticism (Skarbez et al., 2017). Some methods for objectively examining these experiences have been tested and found viable, for example, Jennett et al. (2008) found that the number of eye fixations while playing a game correlates with the level of immersion the participants reported, and Ijsselsteijn, de Ridder, Freeman, and Avons (2000) examined a reaction time measure for measuring presence. While testing these experiences using an objective measure was not possible in this study, future studies could examine the model using a combination of objective and subjective measures.

Due to the limited number of questions available, the questionnaire focused on a subjective self-evaluation, i.e., the effects of the experiences, of PP, social presence, self presence, and INV, whereas questions for the other variables examined the causes. Future studies could redo the study but examine PP, social presence, self presence, and INV using questions examining the causes for these experiences rather than their effects. Alternatively, a combination of both could provide even more comprehensive results.

The data analysis also revealed several issues caused by the limitations. As presented in the statistical analysis subchapter (Chapter 6.2), the Shapiro-Wilk test of normality resulted in the null hypothesis of normality being rejected. This could mean a few things. It could indicate a potential bias with VR set owners to report the experience better than it was. As most VR sets are still expensive (McCarthy, 2019), VR set owners might want to present VR in a more positive light to justify the money they spent on it. Additionally, perhaps they want to see VR succeed and grow as a field, which resulted in them reporting their experiences more positively than they were. An alternative explanation is that VR is stated to be an immersive technology due to its ability to better elicit immersion and presence than alternative forms of technology (e.g., Cummings & Bailenson, 2016).

The confirmatory factor analysis showed that Lee's (2021) proposed model exhibited poor discriminant and convergent validity as well as a poor goodness-of-fit with this dataset. This could indicate that there are problems with the model Lee (2021) proposed. However, as mentioned earlier, the more likely reason for this was that the questionnaire constructed for this study was not sufficient for examining the model. There were a number of factors that contributed to this.

As the model had not been previously empirically examined, the questionnaire created in this study was the first attempt to create a questionnaire for the model. Furthermore, while PP, self presence, social presence, and INV have been studied in the past and established measurement scales for these variables have been developed, these do not exist for the other variables Lee (2021) presented. This means that the measurement scales created for the engagement variables (sensorimotor, task/motor, and narrative) as well as for the interestingness, plausibility and interactivity variables used in this study were based on the authors interpretation of the descriptions Lee (2021) provided in his article. Then, perhaps the questions chosen for the variables were a poor fit, or the boundaries between the variables were not clearly set. Therefore, it is suggested here that future studies should develop and carefully test new scales for examining the variables of Lee's (2021) model. While these created scales were found to not be valid, they could function as a starting point for further scale and questionnaire development for examining the validity of the model in the future.

In addition, due to the aforementioned limitations in questionnaire length, the questionnaire attempted to examine complicated concepts using just a few questions. This could be a reason the Cronbach's alpha test (Table 6) of the original model showed poor internal consistencies for the sensorimotor engagement, task/motor engagement, narrative engagement, plausibility, and interactivity variables, as each variable only had three questions each. Future research should examine Lee's (2021) model using a more substantial number of questions for these variables. In addition, as noted before, future studies examining the model should set clearer boundaries for the variables to improve the validity of the model.

Due to these reasons, examining the full model Lee (2021) proposed was not possible, and the focus of the study had to be changed. While this provided interesting findings on the connection of interestingness to the other variables and some initial empirical findings for the validity of a part of Lee's (2021) model, it is recognized that these results may not be the same when the entirety of the model is considered. Furthermore, the removal of a number of questions from the variables meant that while they retained their core concepts, they no longer covered them as comprehensively. For example, the self presence variable had a greater emphasis on the concept of embodiment as Lee (2021) proposed. Therefore, as mentioned previously, future studies should develop and validate appropriate measurement scales for the variables in Lee's (2021) model and examine its validity when all its components are considered. Furthermore, while this study found that interestingness had a positive effect on all the dimensions of IE, it is possible that the lack of other variables and the limitations presented here could influence these results. Therefore, future studies examining Lee's (2021) model should examine if this result is still valid when the full model with all its variables are considered. The same goes for the connections between IE and INV and social presence.

In addition, as SEM did not allow to account for the correlations between the main dimensions which were found to exist (Table 16), the results of the analysis of the structural model do not take these into account. It is possible that when these correlations are accounted for, its results could be different. Future studies should examine if the correlations between the dimensions have an influence on their impact on IE.

As the results showed, the R^2-value indicates that PP, social presence, self presence, and INV explain 41,9% of the variance in IE. It is possible that re-examining Lee's (2021) model using more substantial measures for these variables as well, could improve their explanatory capabilities and provide more comprehensive results for the validity of the model. Alternatively, it could mean that that IE is influenced by a number of different factors which were not accounted for in this study, for example, the other factors of Lee's (2021) model and/or the factors that were presented in chapter 4 (Chapter 4). Furthermore, the measure for immersion used in this study was a very simple, one question measure due to the aforementioned limitations in questionnaire length. The experience of immersion is a complicated subjective experience, and while the measure has been validated (Jennett et al., 2008), it provides little data on the experience. Re-examining Lee's (2021) model and perhaps re-examining the model examined in this study using a more substantial measure of immersion could provide different results.

While this study could not examine Lee's (2021) model fully, this study provided some empirical data for the existence of the connections Lee (2021) hypothesized in his article. It is important to note, however, that the results indicated that there are correlations between the variables, but that does not mean that there is causality between them (Tompkins, 1992). It is up to future researchers to examine the directions of these connections and verify the validity of the conceptual model. In addition, while Lee (2021) created the model with XR technologies in mind, this thesis only examined it in the context of VR. Therefore, the results of this study are not generalizable to other XR technologies. Future research should examine the validity of the model using other XR technologies.

Finally, this thesis placed heavy emphasis on Lee's (2021) model and the connections within it. The experience of immersion has not been widely researched in the field of VR, therefore, a number of the factors presented in chapter 4.2 rely on the connection between presence and IE Lee (2021) suggested for their influence on the experience of immersion. However, Lee's (2021) article is currently in preprint, meaning that it has not been peer-reviewed, and the model has not been empirically validated. While this study took the first step in empirically examining the model, it was not without its problems, and further research on the model must be conducted before its validity can be proven. Therefore, as future studies examine the validity of the model, they should also further validate the results and findings presented in this thesis.

8 CONCLUSION

As VR is finally starting to live up to the promises it made 30 years prior, VR technologies are becoming increasingly popular not only for private consumers but for business enterprises and various professional fields (Angelov et al., 2020; Slater & Sanchez-Vives, 2016). While nowadays VR is still heavily marketed for entertainment purposes, research has shown that VR has significant and potentially revolutionary applications outside the field of entertainment, and its use-cases are only expected to increase as the adoption of VR technologies increases (Slater & Sanchez-Vives, 2016). Therefore, researching ways to provide the best possible experience for its users is of great significance.

The experience of immersion has been stated as a key component of the enjoyment of games as well as good interactive media experiences (e.g., Jennett et al., 2008). Therefore, this thesis set out to answer the research question of how the experience of immersion is achieved with modern VR technologies.

The literature review done in this thesis found four categories of factors that have been found to influence the different dimensions of the experience of immersion in prior research. However, due to the difficulties surrounding the definitions of immersion, presence, and involvement, as well as confusion about their relationships across fields of research, there is still a lot of uncertainty in the fields researching these experiences (Jennett et al., 2008; Lee, 2021; Nilsson et al., 2016). In addition, studies have only recently started to examine the experience of immersion in the context of VR (Mütterlein, 2018). The majority of prior research on the experience focuses on the experience of immersion with different technologies. While this past research provides a solid groundwork, empirical testing is required to examine whether these findings are valid in the context of VR.

Therefore, the conceptual model that Lee (2021) posed is a necessary and important step into examining the experience of immersion in the field of VR. This model provides the means to further understand how the experience of immersion is achieved using VR technologies. Furthermore, it allows for a more detailed examination of how different factors influence the experience via their influence on its dimensions. This increased understanding can help to improve

VR software and hardware so that it may, in the future, fully reach its revolutionary potential (Slater & Sanchez-Vives, 2016).

The empirical study conducted in this thesis has managed to take the first steps into empirically examining Lee's (2021) conceptual model on the experience of immersion. While the empirical study could not examine the model fully, it provided a good starting point for its future examination, as it presented a number of interesting insights and notes about it that should be considered in future examinations of the model.

If future research can further examine and eventually validate Lee's (2021) model, it could yield very beneficial research findings for VR software developers and hardware engineers, as well as researchers examining the fields of immersion, presence, and VR research. VR developers and engineers could benefit from what factors to pay attention to to create better, more enjoyable VR experiences for users both in entertainment and professional uses. In addition, it could provide more valuable data on the experience of immersion and its dimensions to researchers researching these fields. The following two subchapters will go into more detail about the possible implications of this thesis for research and practice.

8.1 Contributions to research

This thesis adds to the body of research on immersion, virtual reality, and more importantly, to the growing body of research on the relationship between immersion and presence, as well as to the limited research done on the experience of immersion in the context of VR. In addition, it contributes to research by encapsulating a large amount of research done on immersion, including the difficulties surrounding its definitions across research fields, and its complicated relationship with presence and the field of presence and VR research. Furthermore, it extends the conceptual model of immersion presented by Lee (2021). Whereas Lee (2021) proposed general factors of content and technology that influence the experience of immersion, this thesis presented a number of specific features and factors related to modern VR sets and their use, which have been reported to influence the experience of immersion and its dimensions from prior research. Additionally, it presented how some of the most common problems related to VR, namely screen-door effect, cyber sickness, and ergonomics of the HMDs, influence the experience of immersion. This provides future researchers deeper knowledge of the experience of immersion and the myriad of factors that can potentially influence it in the context of VR. This thesis also provides a starting point for further examining Lee's (2021) conceptual model. Examining the validity of Lee's (2021) model is significant since it considers (physical) presence as a component of the experience of immersion, therefore bridging the gap between presence research and the research on the experience of immersion. Finally, the study provides further evidence for the relationship between immersion and presence.

There are also several topics for future research that this thesis highlights. First and foremost, there are still conflicting views on the definition of immersion. It is proposed that future research should standardize different terms for the different views of immersion to help prevent confusion when discussing and researching the concept. Second, the relationship between presence and the experience of immersion has been long debated, and no definitive answers for their relationship has been found. It is suggested that future research examines their relationship further using commonly agreed upon definitions. Thirdly, the four categories of factors which have been found to influence the experience of immersion and its dimensions need to be empirically examined in the context of VR. Additionally, the connections of the factors with Lee's (2021) model require empirical testing in future studies. Fourthly, the connections found in this study need further examining. While users' interest towards the content has been found to influence INV, there has been little research and debate on its influence on PP, social presence, and self presence. Future research should examine the effect of user interest towards these experiences. Furthermore, the influence of social presence on self presence requires further examination in future studies, as this has not been widely researched. Finally, the lack of effect from social presence on the experience of immersion need further examining. As mentioned in the previous chapter (Chapter 7), there has been debate on the effect of social presence and social interactions on the experience of immersion. Future research should examine if the amount of social interaction has an effect on this connection.

While this thesis took the initial steps in empirically examining Lee's (2021) conceptual model, further examination and evidence is required to prove its validity and usefulness in examining the other influencing factors. Future studies should develop and validate new scales for measuring the concepts that make up Lee's (2021) model. While the questionnaire used in this study was problematic for examining the model due to limitations in length and scope for testing, the questionnaire could be used as a starting point for scale development in future research into the validity of the model.

8.2 Contributions to practice

Firstly, this thesis provides a good starting point for not only individuals but also VR hardware and software developers interested in learning about the experience of immersion in the context of VR and factors that influence it. Secondly, it is commonly understood that a higher level of immersion leads to a more enjoyable experience (e.g., Ermi & Mäyrä, 2005; Pallavicini et al., 2019). Understanding how immersion is achieved and what factors influence it helps VR hardware and software developers understand what to consider when creating VR sets and applications to maximize the experience of immersion they can provide. Furthermore, understanding which factors negatively influence it can help them avoid them or alleviate their effects. Finally, the factors related to

HMDs presented in this thesis can help consumers and companies decide what technical specifications to look for in a VR set to provide a good experience for its users.

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APPENDIX 1 QUESTIONNAIRE FORM

A survey on the experience of Immersion in virtual reality	**Source**
Please answer all the questions *based solely on your most recent* virtual reality experience.	
C1. Age - Under 18, - 18-24 - 25-34 - 35-44 - 45-54 - 55-64 - 65 and over	
C2. Gender - Female - Male - Prefer not to say - Other	
C3. How familiar are you in using a virtual reality set? - 1 (Not at all familiar) – 5 (Very familiar)	
C4. When did the VR experience in question happen? - Today - Within the last week - Within the last two weeks - Over two weeks ago	
C5. How long was the VR experience in question? - Less than 30 minutes - 30 minutes – 1 hour - 1 hour – 2 hours - Over 2 hours	
C6. Which genre was the game/experience in question? - FPS/Shooter - Action - Music/Rhythm - Simulator - Creative - Puzzle, Sports - Role Playing Game - Adventure - Exploration - Social - Other	
C7. Were there other people (human controlled players or computer-controlled agents) in the virtual environment? - Yes - No	
C8. Which VR set did you use? - Oculus Quest 2 - Oculus Quest	

- Oculus Rift S - Oculus Rift - Valve Index HMD - HTC Vive - HTC Vive Pro - HTC Vive Cosmos - HTC Vive Elite - HP Reverb - HP Reverb G2 - Sony Playstation VR - Pimax 5k Plus - Pimax 8K - Other	
The numbers correspond to 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Please read the questions carefully and answer all the questions based *only on the most recent* VR experience you've had.	
Q1. I felt that my senses were completely engaged in the VR experience.	Witmer, Jerome & Singer (2005)
Q2. I felt that the VR system could accurately translate my movement (head, arms, etc.) into the virtual environment.	Lee (2021)
Q3. I felt like there was a delay between my actions and their effects in the virtual environment. *	Baños et al. (2000)
Q4. I felt that the VR experience activated my thinking.	Vorder et al. (2004)
Q5. The VR content was interactive.	Mütterlein (2018)
Q6. My mind was engaged with the tasks/activities I performed in the virtual environment and/or with the virtual environment itself.	Lee (2021)
Q7. I was interested in seeing how the VR experience's events would progress.	Jennett et al. (2008)
Q8. I was engaged with/interested in the narrative of the VR content I experienced.	Lee (2021)
Q9. I was engaged with/interested in the tasks/activities I performed in the virtual environment.	Lee (2021)
Q10. I felt that my perceptions in the virtual environment (visual, somatic, etc.) were congruent.	Baños et al. (2000)
Q11. I felt like what I experienced in the virtual environment fit my expectations about what could happen in a virtual environment.	Baños et al. (2000)
Q12. I found that the sensory information of the virtual environment was consistent. For example, the sound of two metal objects colliding sounded metallic. A visually smooth object felt smooth.	Chertoff, Goldiez & LaViola Jr. (2010)
Q13. I felt like I could concentrate on the tasks or activities rather than on the mechanisms used to perform those tasks or activities.	Witmer et al. (2005)
Q14. I understood the rules of the game/VR experience.	Calvillo-Gaméz, Cairns & Cox (2010)
Q15. I felt that my movements in the virtual environment seemed natural.	Baños et al. (2000)

Q16. I liked the type of VR experience.	Cheng et al. (2014)
Q17. I found the scenario of the VR experience interesting.	Calvillo-Gaméz et al. (2010)
Q18. I felt interested in the tasks/activities I performed in the virtual environment.	Wiebe et al. (2014)
Q19. I had a sense of acting in the virtual environment, rather than operating something from the outside.	Makransky, Lilleholt & Aaby (2017)
Q20. While I was in the virtual environment, I had a sense of "being there."	Makransky et al. (2017)
Q21. Somehow, I felt that the virtual world surrounded me.	Schubert et al. (2001)
Q22. I felt like I was able to imagine the virtual environment as if it were real.	Sas & O'Hare (2003)
Q23. I felt like my sense of being in the virtual environment was stronger than my sense of being in the real world.	Jennett et al. (2008)
Note that another person/people can refer to human controlled characters via online play or computer-controlled agents (friendly, hostile, etc.)	
Q24. I felt like I was in the presence of another person/other people in the virtual environment.	Makransky et al. (2017)
Q25. I felt that the people in the virtual environment were aware of my presence.	Makransky et al. (2017)
Q26. The people in the virtual environment appeared to be sentient (conscious and alive) to me.	Makransky et al. (2017)
Q27. I experienced a high level of interaction with another person/other people in the virtual environment.	Chertoff et al. (2010)
Q28. The other people's intentions in the virtual environment were clear to me.	de Kort, Ijsselsteijn & Poels (2007)
Q29. I believed I was the character I was controlling.	Chertoff et al. (2010)
Q30. When something happened to my virtual body, it felt like it was happening to my real body.	Makransky et al. (2017)
Q31. When I felt an emotional reaction, I felt that my emotional state was appropriate given the events that occurred in the virtual environment at the time.	Chertoff et al. (2010)
Q32. I assumed/played a role while experiencing the virtual environment.	Baños et al. (2000)
Q33. During the VR experience, I felt like my virtual body and my real body became one and the same.	Makransky et al. (2017)
Q34. I didn't notice time passing.	Mütterlein (2018)
Q35. I felt like I forgot about my everyday concerns.	Jennett et al. (2008)
Q36. I forgot about my immediate (real) surroundings during the VR experience.	Mütterlein (2018)
Q37. I got really involved with the VR experience.	McMahan, Bowman,

	Zielinski & Brady (2012)
Q38. I felt like the right thoughts and movements occurred of their own accord.	Mütterlein (2018)
Q39. How immersed did you feel? - 1 (Not at all immersed) – 10 (Very immersed)	Jennett et al. (2008)
Write your email if you wish to enter the Steam gift card raffle. Your email will only be used to contact you in the case you win.	
Note: * indicates a reversed scale	

APPENDIX 2 FULL SAMPLE CHARACTERISTICS

Variable	Category	Frequency (Percent)
Age	18-24	144 (41,5)
	25-34	112 (32,3)
	35-44	45 (13,0)
	45-54	5 (1,4)
	55-64	1 (0,3)
	Under 18	40 (11,5)
Gender	Female	37 (10,7)
	Male	298 (85,9)
	Prefer not to say	11 (3,2)
	Transgender	1 (0,3)
VR set used	HP Reverb	4 (1,2)
	HP Reverb G2	31 (8,9)
	HTC Vive	36 (10,4)
	HTC Vive Cosmos	7 (2,0)
	HTC Vive Elite	2 (0,6)
	HTC Vive Pro	7 (2,0)
	Oculus Quest	21 (6,1)
	Oculus Quest 2	61 (17,6)
	Oculus Rift	17 (4,9)
	Oculus Rift S	27 (7,8)
	Pimax 8K	1 (0,3)
	Sony Playstation VR	11 (3,2)
	Valve Index HMD	106 (30,5)
	Other	16 (4,6)
Genre of experience	Action	27 (7,8)
	Adventure	12 (3,5)
	Creative	11 (3,2)
	Exploration	5 (1,4)
	FPS/Shooter	119 (34,3)
	Music/Rhythm	21 (6,1)
	Puzzle	5 (1,4)
	Role Playing Game	35 (10,1)
	Simulator	29 (8,4)
	Social	25 (7,2)
	Sports	15 (4,3)
	Other	43 (12,4)
Note: N = 347		

APPENDIX 3 STATISTICAL DISTRIBUTIONS OF THE INDICATOR VARIABLES

Question	Mean	Std. Deviation
Q1. I felt that my senses were completely engaged in the VR experience.	4,10	0,768
Q2. I felt that the VR system could accurately translate my movement (head, arms, etc.) into the virtual environment.	4,28	0,753
Q3. I felt like there was a delay between my actions and their effects in the virtual environment. *	1,97	1,190
Q4. I felt that the VR experience activated my thinking.	4,14	0,779
Q5. The VR content was interactive.	4,63	0,644
Q6. My mind was engaged with the tasks/activities I performed in the virtual environment and/or with the virtual environment itself.	4,58	0,698
Q7. I was interested in seeing how the VR experience's events would progress.	4,47	0,746
Q8. I was engaged with/interested in the narrative of the VR content I experienced.	4,10	1,015
Q9. I was engaged with/interested in the tasks/activities I performed in the virtual environment.	4,59	0,636
Q10. I felt that my perceptions in the virtual environment (visual, somatic, etc.) were congruent.	4,22	0,774
Q11. I felt like what I experienced in the virtual environment fit my expectations about what could happen in a virtual environment.	4,30	0,776
Q12. I found that the sensory information of the virtual environment was consistent. For example, the sound of two metal objects colliding sounded metallic. A visually smooth object felt smooth.	3,79	1,031
Q13. I felt like I could concentrate on the tasks or activities rather than on the mechanisms used to perform those tasks or activities	4,17	0,883
Q14. I understood the rules of the game/VR experience.	4,70	0,577
Q15. I felt that my movements in the virtual environment seemed natural.	4,14	0,889
Q16. I liked the type of VR experience.	4,74	0,541
Q17. I found the scenario of the VR experience interesting.	4,61	0,656
Q18. I felt interested in the tasks/activities I performed in the virtual environment.	4,59	0,627
Q19. I had a sense of acting in the virtual environment, rather than operating something from the outside.	4,35	0,816
Q20. While I was in the virtual environment, I had a sense of "being there."	4,32	0,777
Q21. Somehow, I felt that the virtual world surrounded me.	4,30	0,845
Q22. I felt like I was able to imagine the virtual environment as if it were real.	3,95	1,073
Q23. I felt like my sense of being in the virtual environment was stronger than my sense of being in the real world.	3,18	1,344

Q24. I felt like I was in the presence of another person/other people in the virtual environment.	4,00	1,152
Q25. I felt that the people in the virtual environment were aware of my presence.	4,14	1,018
Q26. The people in the virtual environment appeared to be sentient (conscious and alive) to me.	3,97	1,225
Q27. I experienced a high level of interaction with another person/other people in the virtual environment.	3,90	1,176
Q28. The other people's intentions in the virtual environment were clear to me.	4,13	0,953
Q29. I believed I was the character I was controlling.	3,74	1,212
Q30. When something happened to my virtual body, it felt like it was happening to my real body.	2,82	1,337
Q31. When I felt an emotional reaction, I felt that my emotional state was appropriate given the events that occurred in the virtual environment at the time.	3,86	0,987
Q32. I assumed/played a role while experiencing the virtual environment.	3,81	1,167
Q33. During the VR experience, I felt like my virtual body and my real body became one and the same.	3,27	1,260
Q34. I didn't notice time passing.	4,17	0,968
Q35. I felt like I forgot about my everyday concerns.	4,05	1,091
Q36. I forgot about my immediate (real) surroundings during the VR experience.	3,75	1,135
Q37. I got really involved with the VR experience.	4,45	0,693
Q38. I felt like the right thoughts and movements occurred of their own accord.	4,16	0,892
Q39. How immersed did you feel?	8,20	1,164
Note: N = 347, Q39 scale = 1-10, * = reversed.		

APPENDIX 4 SPEARMAN'S CORRELATION MATRIX OF THE INDICATOR VARIABLES

Spearman's correlations

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39
Q1	1	.346**	-0.05	.256**	.167**	.227**	.239**	.216**	.207**	.395**	.265**	.310**	.209**	.109*	.327**	.193**	.182**	.185**	.292**	.374**	.398**	.447**	.314**	.181**	.163**	.118*	.164**	.183**	.278**	.367**	.328**	.160**	.366**	.106*	.200**	.279**	.334**	.326**	.535**
Q2	.346**	1	-.295**	.152**	.250**	.242**	.236**	.154**	.245**	.323**	.265**	.290**	.228**	.250**	.455**	.352**	.288**	.281**	.249**	.267**	.244**	.280**	.135*	.276**	.267**	.305**	.204**	.272**	.284**	.186**	.300**	.144**	.328**	.147**	.203**	.180**	.323**	.297**	.342**
Q3	-0.05	-.295**	1	-0.03	-.372**	-.379**	-.254**	-.108*	-.292**	-.221**	-.243**	-.132*	-.274**	-.342**	-.227**	-.359**	-.263**	-.326**	-.267**	-.211**	-.147**	-.111*	0.101	-.170**	-.210**	-.144**	-.111*	-.195**	-0.08	0.097	-0.1	-0.04	-0.1	-0.1	-0.1	-0.05	-.255**	-.238**	-.121*
Q4	.256**	.152**	-0.03	1	.195**	.301**	.233**	.226**	.283**	.203**	.215**	.224**	.240**	.185**	.197**	.228**	.246**	.291**	.230**	.280**	.268**	.251**	.202**	.169**	.192**	.144**	.136*	0.099	.125*	0.094	.275**	.236**	.180**	.186**	.328**	.285**	.341**	.277**	.227**
Q5	.167**	.250**	-.372**	.195**	1	.494**	.433**	.187**	.437**	.291**	.360**	.152**	.350**	.465**	.295**	.455**	.412**	.420**	.316**	.243**	.253**	.237**	0.029	.225**	.255**	.165**	.168**	.191**	.181**	-0.07	.178**	.181**	.146**	.231**	.180**	.152**	.399**	.268**	.184**
Q6	.227**	.242**	-.379**	.301**	.494**	1	.430**	.283**	.482**	.285**	.302**	.214**	.365**	.394**	.304**	.488**	.357**	.451**	.439**	.346**	.270**	.265**	0.073	.256**	.303**	.216**	.142**	.211**	.186**	0.013	.229**	.245**	.159**	.197**	.198**	.157**	.398**	.287**	.253**
Q7	.239**	.236**	-.254**	.233**	.433**	.430**	1	.515**	.419**	.427**	.277**	.178**	.311**	.321**	.251**	.437**	.449**	.430**	.390**	.390**	.345**	.353**	.145**	.285**	.303**	.219**	.263**	.213**	.202**	.134*	.298**	.343**	.177**	.206**	.203**	.212**	.446**	.359**	.309**
Q8	.216**	.154**	-.108*	.226**	.187**	.283**	.515**	1	.331**	.174**	.186**	.141**	.237**	.198**	.167**	.224**	.380**	.253**	.316**	.277**	.229**	.276**	.212**	.213**	.184**	.106*	.144**	.142**	.170**	.191**	.284**	.286**	.161**	.138**	.133*	.205**	.354**	.229**	.241**
Q9	.207**	.245**	-.292**	.283**	.437**	.482**	.419**	.331**	1	.354**	.337**	.208**	.354**	.507**	.275**	.489**	.477**	.563**	.398**	.350**	.335**	.299**	0.071	.240**	.333**	.238**	.166**	.253**	.203**	0.09	.279**	.292**	.221**	.249**	.210**	.174**	.447**	.324**	.257**
Q10	.395**	.323**	-.221**	.203**	.291**	.285**	.427**	.174**	.354**	1	.347**	.302**	.321**	.319**	.419**	.286**	.304**	.281**	.328**	.415**	.369**	.417**	.273**	.313**	.328**	.295**	.284**	.334**	.164**	.177**	.299**	.136*	.257**	.180**	.228**	.218**	.407**	.400**	.383**
Q11	.265**	.265**	-.243**	.215**	.360**	.302**	.277**	.186**	.337**	.347**	1	.237**	.336**	.349**	.395**	.318**	.313**	.314**	.315**	.311**	.289**	.276**	0.103	.345**	.376**	.283**	.241**	.291**	.202**	0.062	.275**	0.097	.227**	.212**	.300**	.202**	.301**	.340**	.253**
Q12	.310**	.290**	-.132*	.224**	.152**	.214**	.178**	.141**	.208**	.302**	.237**	1	.310**	.126*	.246**	.155**	.241**	.188**	.245**	.157**	.252**	.300**	.313**	0.036	0.037	-0.01	-0.01	0.097	.178**	.275**	.132*	.141**	.265**	0.094	.163**	.208**	.182**	.205**	.367**
Q13	.209**	.228**	-.274**	.240**	.350**	.365**	.311**	.237**	.354**	.321**	.336**	.310**	1	.443**	.380**	.295**	.297**	.364**	.355**	.283**	.308**	.306**	.245**	.221**	.252**	.234**	.214**	.149**	.257**	.143**	.252**	.207**	.273**	.190**	.250**	.284**	.365**	.412**	.342**
Q14	.109*	.250**	-.342**	.185**	.465**	.394**	.321**	.198**	.507**	.319**	.349**	.126*	.443**	1	.346**	.536**	.463**	.453**	.343**	.296**	.285**	.217**	-0.01	.300**	.326**	.274**	.240**	.296**	0.105	-0.06	.206**	.141**	.110*	.264**	.223**	.160**	.452**	.332**	.179**
Q15	.327**	.455**	-.227**	.197**	.295**	.304**	.251**	.167**	.275**	.419**	.395**	.246**	.380**	.346**	1	.328**	.306**	.313**	.368**	.345**	.343**	.381**	.207**	.302**	.289**	.294**	.241**	.269**	.229**	.219**	.291**	.150**	.286**	.204**	.163**	.213**	.374**	.331**	.386**
Q16	.193**	.352**	-.359**	.228**	.455**	.488**	.437**	.224**	.489**	.286**	.318**	.155**	.295**	.536**	.328**	1	.517**	.502**	.377**	.296**	.310**	.192**	-0.03	.291**	.393**	.296**	.181**	.338**	.158**	-0.04	.242**	.148**	0.105	.176**	.189**	.105*	.426**	.277**	.286**
Q17	.182**	.288**	-.263**	.246**	.412**	.357**	.449**	.380**	.477**	.304**	.313**	.241**	.297**	.463**	.306**	.517**	1	.580**	.339**	.305**	.298**	.318**	.142**	.295**	.350**	.235**	.222**	.281**	.198**	.111*	.225**	.298**	.139**	.247**	.218**	.183**	.472**	.319**	.333**
Q18	.185**	.281**	-.326**	.291**	.420**	.451**	.430**	.253**	.563**	.281**	.314**	.188**	.364**	.453**	.313**	.502**	.580**	1	.322**	.351**	.329**	.309**	.166**	.249**	.367**	.258**	.223**	.295**	.273**	0.061	.272**	.270**	.172**	.222**	.267**	.177**	.451**	.363**	.281**
Q19	.292**	.249**	-.267**	.230**	.316**	.439**	.390**	.316**	.398**	.328**	.315**	.245**	.355**	.343**	.368**	.377**	.339**	.322**	1	.569**	.481**	.447**	.261**	.384**	.390**	.290**	.329**	.358**	.316**	.265**	.363**	.318**	.337**	.217**	.265**	.211**	.424**	.395**	.392**
Q20	.374**	.267**	-.211**	.280**	.243**	.346**	.390**	.277**	.350**	.415**	.311**	.157**	.283**	.296**	.345**	.296**	.305**	.351**	.569**	1	.645**	.566**	.330**	.381**	.365**	.338**	.287**	.260**	.323**	.272**	.405**	.283**	.359**	.213**	.292**	.305**	.458**	.350**	.472**
Q21	.398**	.244**	-.147**	.268**	.253**	.270**	.345**	.229**	.335**	.369**	.289**	.252**	.308**	.285**	.343**	.310**	.298**	.329**	.481**	.645**	1	.584**	.373**	.306**	.314**	.291**	.238**	.208**	.281**	.263**	.449**	.261**	.342**	.162**	.292**	.304**	.468**	.393**	.507**
Q22	.447**	.280**	-.111*	.251**	.237**	.265**	.353**	.276**	.299**	.417**	.276**	.300**	.306**	.217**	.381**	.192**	.318**	.309**	.447**	.566**	.584**	1	.501**	.308**	.303**	.249**	.216**	.295**	.411**	.365**	.392**	.310**	.456**	.215**	.299**	.352**	.489**	.396**	.568**
Q23	.314**	.135*	0.101	.202**	0.029	0.073	.145**	.212**	0.071	.273**	0.103	.313**	.245**	-0.01	.207**	-0.03	.142**	.166**	.261**	.330**	.373**	.501**	1	.238**	.199**	.212**	.213**	.198**	.349**	.468**	.335**	.239**	.420**	.274**	.369**	.390**	.301**	.357**	.415**
Q24	.181**	.276**	-.170**	.169**	.225**	.256**	.285**	.213**	.240**	.313**	.345**	0.036	.221**	.300**	.302**	.291**	.295**	.249**	.384**	.381**	.306**	.308**	.238**	1	.747**	.721**	.681**	.434**	.282**	.216**	.407**	.109*	.268**	.293**	.214**	.204**	.340**	.420**	.286**
Q25	.163**	.267**	-.210**	.192**	.255**	.303**	.303**	.184**	.333**	.328**	.376**	0.037	.252**	.326**	.289**	.393**	.350**	.367**	.390**	.365**	.314**	.303**	.199**	.747**	1	.707**	.625**	.508**	.258**	.167**	.371**	.113*	.254**	.335**	.271**	.215**	.378**	.405**	.267**
Q26	.118*	.305**	-.144**	.144**	.165**	.216**	.219**	.106*	.238**	.295**	.283**	-0.01	.234**	.274**	.294**	.296**	.235**	.258**	.290**	.338**	.291**	.249**	.212**	.721**	.707**	1	.702**	.417**	.271**	.226**	.306**	0.031	.234**	.279**	.235**	.167**	.321**	.401**	.277**
Q27	.164**	.204**	-.111*	.136*	.168**	.142**	.263**	.144**	.166**	.284**	.241**	-0.01	.214**	.240**	.241**	.181**	.222**	.223**	.329**	.287**	.238**	.216**	.213**	.681**	.625**	.702**	1	.475**	.270**	.210**	.279**	0.057	.275**	.275**	.194**	.133*	.299**	.390**	.241**
Q28	.183**	.272**	-.195**	0.099	.191**	.211**	.213**	.142**	.253**	.334**	.291**	0.097	.149**	.296**	.269**	.338**	.281**	.295**	.358**	.260**	.208**	.295**	.198**	.434**	.508**	.417**	.475**	1	.288**	.151**	.292**	.128*	.249**	.179**	.123*	.121*	.272**	.358**	.214**
Q29	.278**	.284**	-0.08	.125*	.181**	.186**	.202**	.170**	.203**	.164**	.202**	.178**	.257**	0.105	.229**	.158**	.198**	.273**	.316**	.323**	.281**	.411**	.349**	.282**	.258**	.271**	.270**	.288**	1	.458**	.333**	.342**	.487**	.237**	.303**	.295**	.360**	.283**	.406**
Q30	.367**	.186**	0.097	0.094	-0.07	0.013	.134*	.191**	0.09	.177**	0.062	.275**	.143**	-0.06	.219**	-0.04	.111*	0.061	.265**	.272**	.263**	.365**	.468**	.216**	.167**	.226**	.210**	.151**	.458**	1	.375**	.257**	.550**	.210**	.228**	.286**	.209**	.263**	.418**
Q31	.328**	.300**	-0.1	.275**	.178**	.229**	.298**	.284**	.279**	.299**	.275**	.132*	.252**	.206**	.291**	.242**	.225**	.272**	.363**	.405**	.449**	.392**	.335**	.407**	.371**	.306**	.279**	.292**	.333**	.375**	1	.345**	.431**	.201**	.268**	.209**	.350**	.410**	.314**
Q32	.160**	.144**	-0.04	.236**	.181**	.245**	.343**	.286**	.292**	.136*	0.097	.141**	.207**	.141**	.150**	.148**	.298**	.270**	.318**	.283**	.261**	.310**	.239**	.109*	.113*	0.031	0.057	.128*	.342**	.257**	.345**	1	.313**	.176**	.242**	.171**	.303**	.238**	.288**
Q33	.366**	.328**	-0.1	.180**	.146**	.159**	.177**	.161**	.221**	.257**	.227**	.265**	.273**	.110*	.286**	0.105	.139**	.172**	.337**	.359**	.342**	.456**	.420**	.268**	.254**	.234**	.275**	.249**	.487**	.550**	.431**	.313**	1	.239**	.343**	.294**	.360**	.355**	.420**
Q34	.106*	.147**	-0.1	.186**	.231**	.197**	.206**	.138**	.249**	.180**	.212**	0.094	.190**	.264**	.204**	.176**	.247**	.222**	.217**	.213**	.162**	.215**	.274**	.293**	.335**	.279**	.275**	.179**	.237**	.210**	.201**	.176**	.239**	1	.551**	.412**	.351**	.387**	.203**
Q35	.200**	.203**	-0.1	.328**	.180**	.198**	.203**	.133*	.210**	.228**	.300**	.163**	.250**	.223**	.163**	.189**	.218**	.267**	.265**	.292**	.292**	.299**	.369**	.214**	.271**	.235**	.194**	.123*	.303**	.228**	.268**	.242**	.343**	.551**	1	.437**	.444**	.410**	.294**
Q36	.279**	.180**	-0.05	.285**	.152**	.157**	.212**	.205**	.174**	.218**	.202**	.208**	.284**	.160**	.213**	.105*	.183**	.177**	.211**	.305**	.304**	.352**	.390**	.204**	.215**	.167**	.133*	.121*	.295**	.286**	.209**	.171**	.294**	.412**	.437**	1	.453**	.382**	.345**
Q37	.334**	.323**	-.255**	.341**	.399**	.398**	.446**	.354**	.447**	.407**	.301**	.182**	.365**	.452**	.374**	.426**	.472**	.451**	.424**	.458**	.468**	.489**	.301**	.340**	.378**	.321**	.299**	.272**	.360**	.209**	.350**	.303**	.360**	.351**	.444**	.453**	1	.514**	.497**
Q38	.326**	.297**	-.238**	.277**	.268**	.287**	.359**	.229**	.324**	.400**	.340**	.205**	.412**	.332**	.331**	.277**	.319**	.363**	.395**	.350**	.393**	.396**	.357**	.420**	.405**	.401**	.390**	.358**	.283**	.263**	.410**	.238**	.355**	.387**	.410**	.382**	.514**	1	.417**
Q39	.535**	.342**	-.121*	.227**	.184**	.253**	.309**	.241**	.257**	.383**	.253**	.367**	.342**	.179**	.386**	.286**	.333**	.281**	.392**	.472**	.507**	.568**	.415**	.286**	.267**	.277**	.241**	.214**	.406**	.418**	.314**	.288**	.420**	.203**	.294**	.345**	.497**	.417**	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).