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Realism and Experiments: Investigating Virtual Reality Experiments

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Abstract

Experimental research is a fundamental component of scientific inquiry, but the realism of experimental settings may be limited due to a trade-off between internal and external validity. Virtual Reality technology offers a potential solution to this problem by creating highly controlled, yet realistic experimental settings. In this study, we investigate the potential of VR to increase perceived realism in experimental research by identifying and examining the effects of VR experiments on participants' perceived realism. In our experiment, we compare the level of perceived realism between artificial scenarios presented as text vignettes and in VR. Our findings indicate that VR experiments elicite a significantly higher level of perceived realism compared to text-based experiments. Additionally, we use partial least squares structural equation modeling to investigate the identified concepts. We recommend that researchers consider using VR technology to enhance the realism of experimental settings and improve the validity of their findings.

Keywords: virtual reality, experiment, realism, immersion, flow, presence, telepresence

Introduction

Conducting experiments is an important aspect of science and research (Martínez Pastor & Fernánez Lozano, 2022). They contribute to "understanding causal relationships in the real world, with delicate control and precision, at unprecedented scales" (Bapna et al., 2018, p. 1) and enable the confirmation of theories by investigating the effects that independent variables have on dependent variables (Cahenzli et al., 2021; Webster & Sell, 2014). Since the emergence of digital technologies, the possibilities to conduct experiments have expanded. New ways of recruiting diverse participants (e.g., via MTurk[1]) and carrying out

[1] Amazon Mechanical Turk (or MTurk for short) is a crowdsourcing platform that was initially created to act as an online labor market that allows businesses to outsource tasks. Now it is also used to recruit diverse experiment participants (Strickland & Stoops, 2019).

experiments (e.g., online) have emerged (Bapna et al., 2018; Hergueux & Jacquemet, 2015; Karahanna et al., 2018). Based on the aim of the individual experiment, researchers usually choose between conducting a laboratory experiment or a field experiment (Bapna et al., 2018; List, 2011). When making this choice, three main criteria must be considered (McGrath, 1981). First, the level of external validity (i.e., generalizability), which is the ability to generalize the results of the experiment beyond the scope of the environmental setting, must be maximized (Hogarth, 2005; Karahanna et al., 2018). Second, internal validity, which is the control over the environment and behavior influencing variables, must be ensured (Cahenzli et al., 2021; Karahanna et al., 2018). Last, the "realism of the context [in which] behaviors are observed" (Karahanna et al., 2018, p. iv) has to be considered. If external validity and realism are considered to be the most important factors, field experiments should be conducted. When the research's main focus lies on internal validity, laboratory experiments are performed (Bapna et al., 2018; Cahenzli et al., 2021). However, focusing on one or two of the above-mentioned criteria leads to a neglect of the rest (McGrath, 1981). Consequently, this leads to researchers facing a trade-off between choosing experiments with high internal validity (with control over extraneous variables) and experiments with high external validity (with a high degree of realism) (Bapna et al., 2018; McGrath, 1981). Therefore, there may be a lack of realism in some experiments (Dennis & Valacich, 2001; Karahanna et al., 2018). However, the importance of realism in experiments must not be underestimated, since realism ensures that the results of the experiments can be applied in practice. Hence, there should be a strong equivalence between the experimental situation and the real situation, and realism should not be neglected when conducting experiments (Dennis & Valacich, 2001; Lonati et al., 2018; Sjøberg et al., 2002).

Traditionally, experimental research, especially in fields like psychology and social sciences, has often presented scenarios to participants through text or verbal descriptions (Finch, 1987). These methods are used to standardize the experiment and ensure that every participant receives the same input or stimulus. Nevertheless, we think the stimuli and inputs are far from feeling *real*. Virtual Reality (VR) can be applied to bridge the gap between enabling a controlled setting, as seen in laboratory experiments, and providing a realistic setting that might allow for the generalizability of the retrieved data similar to field studies (Hogarth, 2005; Karahanna et al., 2018; Pan & Hamilton, 2018; Rovira et al., 2009; Slater & Sanchez-Vives, 2016). VR provided by a head-mounted display (HMD) enables participants to fully immerse themselves in a situation and perceive it as real (Pierce & Aguinis, 1997; Slater, 2009), and therefore makes it a suitable tool for conducting realistic experiments. VR technologies have been researched in many fields, an example of which is education (Kamińska et al., 2019). For instance, the impact of the use of VR on learning success has been examined (Hanson & Shelton, 2008; Yang et al., 2020). Aside from that, applications in marketing (Palupski, 1995), organizational behavior research (Pierce & Aguinis, 1997), and psychology (experimental behavior research) (Gaggioli, 2001; Pan & Hamilton, 2018) have been investigated. Furthermore, uses in skill training have been discussed (Kniffin et al., 2014). However, to our knowledge, VR as a tool for achieving realistic situations in scientific experiments has been scarcely researched in IS and is subject to current research (Machemehl, 2022). The special feature of the experiments conducted in VR in our scope opposed to most usual VR applications, is that they should be perceived as real reality and not as alternative (artificial) reality. This is what we call perceived realism. However, individuals may experience a virtual environment as a game-like space rather than a reality, despite being fully immersed in the experience. This highlights the importance of understanding the nuances of user experiences in virtual environments and the need to consider the subjective perceptions and interpretations of users when evaluating the effectiveness of virtual reality for experiments. In the Information Systems (IS) domain, the focus is often on understanding and enhancing user interactions with technology. Virtual Reality stands out as a powerful tool in this regard. With VR, we can create digital environments that mirror real-world scenarios, allowing users to fully immerse themselves. This immersion is pivotal for IS research as it enables a credible experimental situation where users can engage naturally with the technology.

Thus, we intend to explore the possibility of using VR instead of traditional text to achieve more realistic experimental settings in IS research and in doing so answer the following research questions (RQs):

> **RQ1.** What are the key elements in VR technologies that influence the creation of a realistic environment suitable for scientific experimentation?

RQ2. How do these key elements impact participants' perception of realism when compared to traditional text-based vignettes?

To answer these questions regarding realism in experiments in VR compared to text, we conducted an experiment using the two different experimental media – a traditional (text-based) medium and one using VR technologies. We transferred the text-based vignette of Homburg (2022) into a VR environment and conduct a study with two randomized groups of participants. One group was presented with an adapted text-based vignette by Homburg (2022) whereas the other group experienced the described scenario in a self-developed virtual environment. We specifically chose the two experimental media to additionally contribute with a comparison between traditional text vignettes and VR vignettes.

Research Background

To address the potential issue of a lack of realism in some experiments, it is essential to comprehend which concepts are relevant for a realistic experimental setting. For this reason, we examined the literature regarding concepts that might influence perceived realism. We focused on key elements that are induced by VR. Three main concepts were identified during this research: immersion, presence, and flow. These terms will be defined in this chapter. Subsequently, we will give a visual overview of the three concepts and their relation to each other and perceived realism.

Immersion

The term "immersion" relates to a psychological state in which the user is completely absorbed in the (virtual/experimental) environment (Burdea & Coiffet, 2003; Chan et al., 2019; Witmer & Singer, 1998). Immersion is what "technology delivers from an objective point of view" (Slater, 2003, p.1) to put users in that psychological state. It leads to users fully focusing on the virtual world and temporarily forgetting the real one (Chan et al., 2019). A (virtual) environment with a continuous stream of stimuli and experiences enabled by multiple different sensory channels and a high degree of real-time interaction fosters immersion (Burdea & Coiffet, 2003; Chan et al., 2019; Witmer & Singer, 1998). Based on the extent of immersion in a VR application, three different levels of immersion in VR can be distinguished: non-immersive, semi-immersive, and immersive VR. Non-immersive VR applications only allow the user to interact with the environment through traditional input mediums such as keyboards and mice in combination with a computer screen (Costello, 1997; Freude et al., 2020; Zeng & Richardson, 2016). As a result, the user does not feel fully isolated from the real world. This type of VR is often used due to the lower costs of equipment compared to the HMDs, which are used in more immersive VR applications (Freude et al., 2020; Zeng & Richardson, 2016). Semi-immersive VR, however, exceeds the non-immersive VR by additionally offering more and bigger display monitors or projection screens (Zeng & Richardson, 2016). On the other end of the spectrum is immersive VR. On this level of immersion, the user is fully absorbed in the virtual environment without feeling any interaction or sensory input from the real world (Burdea & Coiffet, 2003; Chan et al., 2019; Zeng & Richardson, 2016). In this context, HMD-enabled VR formats offer "a user-centered head-tracked view with a wide angle stereoscopic vision, and interactive control, providing visual and audio immersion" (Zeng & Richardson, 2016, p. 2). This creates interactive three-dimensional scenarios in which the users can be immersed (Freude et al., 2020; Wexelblat, 1993). In addition, immersive virtual environments can increase "sensory fidelity" and the user's feeling of being physically present (Bowmann & McMahan, 2007; Colbert et al., 2016; Or et al., 2022). Thus, a high level of immersion positively influences the sense of presence (Slater, 2003; Slater & Usoh, 1994). Several factors influencing immersion have been identified in the reviewed literature. Some include the natural modes of interactions and the voluntary control of actions (Freude et al., 2020; Slater & Sanchez-Vives, 2016). Freude et al. (2020) refer to this as "agency". Furthermore, the perception of free self-movement, isolation from the physical environment, and the perception of self-inclusion in the virtual environment are factors that impact immersion (Or et al., 2022; Witmer & Singer, 1998). In addition, some authors point out the importance of utilizing several types of sensorial feedback to increase immersion (Burdea & Coiffet, 2003). In contrast, text-based scenarios rely on the pure imagination of individuals.

Presence

The next concept, presence, is enabled by immersion (Slater, 2003). Presence is "the subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer & Singer, 1998, p. 225). A sign of presence in virtual environments (VE) would be a "sense of being there" (Slater, 2003, p. 4). The combination of sensory data with perceptual processing makes this possible in VE. As a result, people behave as they would in the real world (Or et al., 2022; Slater, 2003). In some cases, the term presence is also used synonymously with the concept of an "embodiment", which refers to the ability to control a virtual body. It means that the user can conduct "practices of the body" (Taylor, 2002, p. 42) with the virtual body in a VE (Kampling, 2018; Schultze, 2010; Schwind et al., 2019; Taylor, 2002). Two types of presence can be distinguished. First, social presence (sometimes called merely "presence", depending on the author) refers to social interactions within the VE and whether they are perceived as warm, sociable, sensitive, personal, or intimate. Second, there is telepresence, which refers, on the one hand, to the medium being used to achieve the state of presence and, on the other hand, to the way that the sense of being present in the VE, is perceived (Animesh et al., 2011; Mütterlein & Hess, 2017; Qiu et al., 2006; Steuer & Reeves, 1992). Our research mainly focuses on telepresence. Presence is an objective that has been regularly investigated in VR literature. Different factors and conditions for presence have been identified. Several authors link immersion to presence (Slater, 2003; Taylor, 2002; Witmer & Singer, 1998). Slater (2003, p. 4), for instance, describes presence as a reaction to a "given level of immersion". Since immersion includes the combination of several sensory modes such as audio effects, it influences the sensory breadth which improves the perception of space (Burdea & Coiffet, 2003; Zeng & Richardson, 2016). In addition to immersion, involvement was also identified as a requirement for presence. Involvement requires focusing one's attention and energy on an interlocking set of VE stimuli. It can be associated with other mediums such as books, movies, and arcade games. To measure presence, the underlying factors that influence immersion and involvement should be measured (Witmer & Singer, 1998). Additionally, Witmer and Singer's (1998) research points out the importance of control. As mentioned in the immersion chapter, control is one factor that affects immersion. It refers to the ability to influence the interaction with the virtual environment and indirectly influences the presence as well (Witmer & Singer, 1998). As previously mentioned, the control of a virtual body is also known as "embodiment" and is another factor that can impact how present the user feels in the virtual environment (Kampling, 2018; Schultze, 2010; Schwind et al., 2019; Taylor, 2002).

Flow

Another concept that is investigated in relation to VR is flow. It is characterized as an absorbing state that allows the merging of action and awareness, an altered perception of time, and a sense of control, which leads to the loss of self-consciousness and a feeling of being shifted into a different reality (Csikszentmihalyi et al., 2005; Redaelli & Riva, 2011). It can be described as "[…] a subjective state that people report when they are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself." (Csikszentmihalyi et al., 2005, p. 600). Flow is considered to be a holistic sensation that results from a person's total involvement in their actions (Csikszentmihalyi, 2000; Nacke & Lindley, 2008). In addition to the previously mentioned characteristics of flow (such as the merging of action and awareness, an altered perception of time, a sense of control, the loss of self-consciousness, and the feeling of being transported into another reality) several additional characteristics were identified such as a deep concentration on the task, intrinsic motivation and a feeling of enjoyment of the users when interacting with the virtual environment (Csikszentmihalyi, 2000; Hassan et al., 2020; Novak et al., 2000). The latter can be used to measure flow (Animesh et al., 2011; Qiu & Benbasat, 2005). Immersion can be seen as a precondition for flow since it contributes to users fully focusing on the virtual world and temporarily forgetting the real one (Chan et al., 2019; Csikszentmihalyi et al., 2005; Nacke & Lindley, 2008; Tin et al., 2019). Additionally, technology-induced (tele-)presence is also associated with the experience of flow (Draper et al., 1998; Slater & Wilbur, 1997; Tamborini & Skalski, 2006; Weibel & Wissmath, 2011).

Realism and Perceived Realism in VR Environments

Last, the concept of realism will be addressed. Since VR combines several sensorial modalities, it contributes to increasing the simulation realism and usefulness of VR applications (Burdea & Coiffet, 2003). According to Slater et al. (2009), visual realism distinguishes two types of realism, namely geometric realism and illumination realism. Geometric realism mainly focuses on how much a virtual object looks like the corresponding real-world object, whereas illumination realism considers the fidelity of the lighting model. Sub-components of visual realism include lighting quality, textures, realistic colors, objects, terrain, and shadow quality (Hvass et al., 2017). Some authors implemented this by importing Light Detection and Ranging (LiDAR) scans of real interiors to allow for a realistic depiction of the objects in the virtual environment (Pöhler et al., 2021). It has been suggested that a high degree of visual realism leads to a higher perception of presence (Hvass et al., 2017). Both types of realism are influenced by the presentation of the situation: HMDs differ in e.g., field of view, resolution, light intensity, and display type. In addition to the visual realism definition of Slater et al. (2009), we also want to incorporate the concept of perceived realism, meaning that the situation is perceived as real and thus realistic behavioral responses occur (Fowler, 2015; Hite et al., 2019; Slater et al., 2009). This is what researchers are usually interested in (Dennis & Valacich, 2001; Karahanna et al., 2018).

Hypotheses Development

Interdependencies According to the Literature

Our literature research showed that the use of VR leads to an enhanced feeling of presence, immersion, and flow compared to other ways of representing artificial scenarios. These concepts will be the starting point for developing our hypotheses. We use the findings from our literature review to develop a relationship map (Watson & Webster, 2020). The relationship map is the black part of Figure 1. Based on the presented literature, we hypothesize that immersion, presence, and flow are enhanced when conducting experiments in VR compared to text-based scenario descriptions (Burdea & Coiffet, 2003; Chan et al., 2019; Csikszentmihalyi et al., 2005; Nacke & Lindley, 2008; Tin et al., 2019). The independent variable "Experiment in VR" serves as a binary indicator whether the experiment was done in VR or through a text scenario.

H1: VR scenario descriptions lead to a higher level of immersion than text scenario descriptions in experiments.

H2: VR scenario descriptions lead to a higher level of presence than text scenario descriptions in experiments.

H3: VR scenario descriptions lead to a higher level of flow than text scenario descriptions in experiments.

Introducing Perceived Realism

To further investigate the impact of the experimental medium and immersion, presence, and flow on the perceived realism in experiments, we propose three main hypotheses and extend the relationship map by our research objective (blue, Figure 1). Due to the possibility of presenting multiple stimuli, VR could contribute to perceiving an (experimental) situation as real (Pierce & Aguinis, 1997) and we propose a model to deeply understand perceived realism in VR experiments.

Immersion can affect perceived realism in experiments. First, immersion leads to a state that allows the user to be completely absorbed in a (virtual/experimental) environment (Burdea & Coiffet, 2003). This leads to them temporarily forgetting the real world (Chan et al., 2019). Immersed participants can block out the "real world" and thus might be able to concentrate on and become involved in the "artificial experimental world". Being absorbed by that experimental environment and immersed in tasks means no further distractions from the real world can interrupt the participant. The attention of the participants is focused on the experimental content. We therefore hypothesize:

H4. There is a positive relationship between immersion and perceived realism in experiments.

We expect that the "feeling of being there" (Slater, 2003, p. 4) that results from presence, contributes to an increased perception of realism. A person experiencing presence forgets about the surroundings and feels teleported into another (real) world. Additionally, presence enables individuals to behave as they would in the real world (Slater, 2009). An individual who can behave as in the real world might also perceive a situation as they would in the real world – as real. The sensation of presence thus leads to a more realistic experience. Therefore, we defined the following hypothesis:

H5. There is a positive relationship between presence and perceived realism in experiments.

We expect a negative relationship between flow and perceived realism. The construct of flow refers to the optimal and enjoyable experiences an individual can obtain by performing an activity (Csikszentmihalyi et al., 2005). Flow is a widely studied construct in the field of human-computer interaction and is defined as a state of mind in which a user's interaction with a system is characterized by feelings of playfulness and exploratory behavior. Flow is a state of mind that is often achieved through a high degree of presence and immersion in virtual environments. When a user experiences a sense of presence and immersion in a virtual environment, they may be more likely to enter a state of flow. However, it is important to note that even in a state of flow, a user may not necessarily perceive the virtual environment as real and may still perceive it as a game-like space (Fetzer et al., 2017).

H6. There is a negative relationship between flow and perceived realism in experiments.

In addition, the literature identified connections between presence and flow (Draper et al., 1998; Hassan et al., 2020; Slater & Wilbur, 1997; Tamborini & Skalski, 2006; Weibel & Wissmath, 2011), immersion and flow (Chan et al., 2019; Csikszentmihalyi, 2000; Nacke & Lindley, 2008; Tin et al., 2019), and immersion and presence (Slater, 2003; Taylor, 2002; Witmer & Singer, 1998). These relations were considered in the construction of our research model in order to properly depict the interdependencies. Yet, since our aim is to identify the impact of immersion, presence, and flow on the perceived realism of experiments, and not to solidify the relations among the concepts, we did not define further hypotheses for these concept-relationships. The following Figure 1 acts as an overview of our research model.

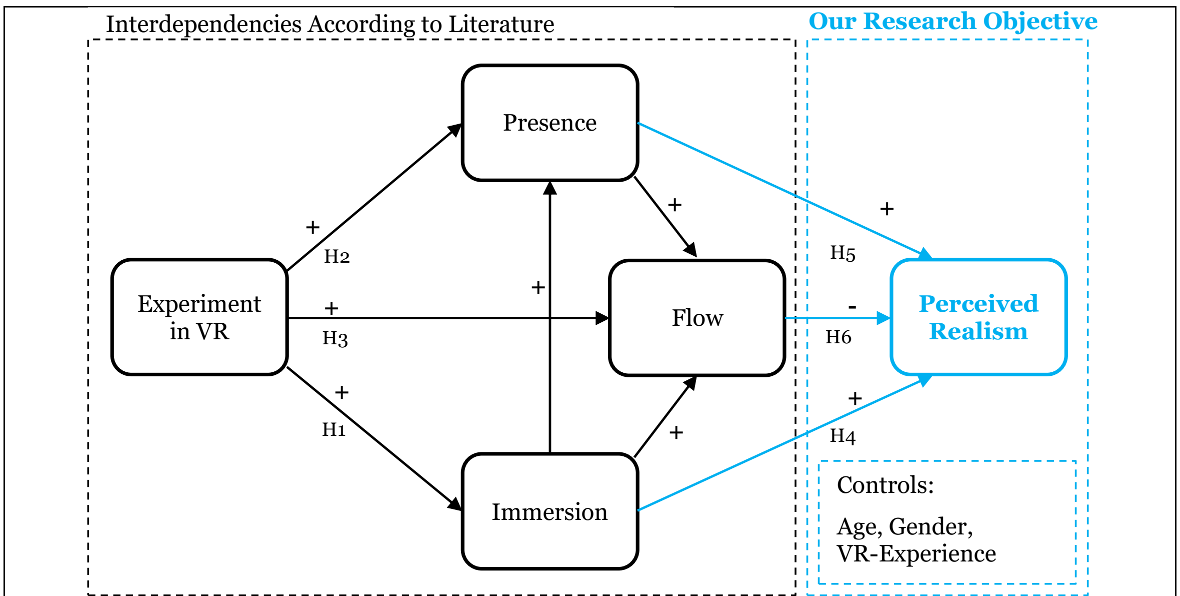

Figure 1. Research Model

Methods

Experiment Background

In our experiment we recreated the scenario of an existing text-based vignette study in VR to compare how the different medium would influence a person's perceived realism. More precisely, we chose the paper by Homburg (2022) in which the author investigated the influence of an individual's trust in their government on their social media use using a text-based vignette. However, while the author examined the relationship between trust and social media use, our focus was not on the specific content of the study, but rather on the level of realism that could be accomplished by conducting such a study in VR instead. We specifically chose this study because content-wise it had a tangible setting, was not overly complicated, and, most importantly, no specialized knowledge was needed for the participant to understand the scenario and carry out the task.

Furthermore, the scenario was documented in detail and the vignette text as well as the questionnaire were provided. While numerous other studies also presented a promising scenario, they did not document their vignettes and questionnaires in detail, which made accurately recreating them unfeasible (Jarvenpaa et al., 1985). The *original vignette* by Homburg (2022) is as follows:

"Trudy lives in a small urban community and travels to a neighboring city four times a week by a public road. Trudy notices that due to weather conditions, the condition of the road deteriorates up to the point where there are big cracks and holes in the road. As Trudy travels down this road regularly, she knows where the cracks and holes are, but she realizes that other people might crash and hurt themselves. Trudy is worried about what might happen to fellow citizens and uses the public social media account of the public works agency responsible for road maintenance to post pictures of the holes and cracks in the road, and to notify the public works agency of the bad condition of the road under her own name." (p. 128)

We decided to conduct two examinations with this scenario, using different mediums. One group would be provided with a VR experience and a follow-up survey, while the other group was provided with a text-based vignette with survey questions, much like in the original study of Homburg (2022). Both groups received a text, which is almost identical to the *original vignette*. The only change made was the adjustment of pronouns because the participant was taking over the role of "Trudy". All participants voluntarily participated.

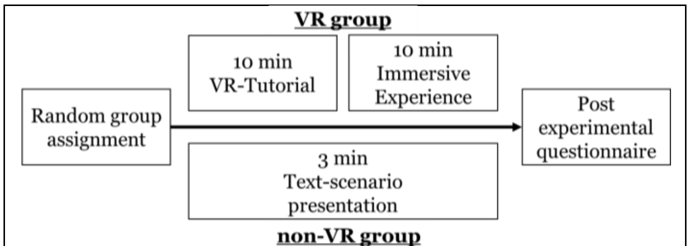

Figure 2. Study Design

Experiment and Survey

The participants were meant to experience the vignette from Homburg's study in a virtual setting by taking on the role of the mentioned person ("Trudy"). Put simply, their task was to walk along a damaged road, take pictures of the potholes, and then publicly post pictures of what they saw. They would perform this task in the virtual environment that would be shown to them through the VR headset while physically being in the same room as the research instructors. The instructors were mainly present to help with the technical setup and answer questions strictly regarding controls. After finishing the task, the participants answered a follow-up survey regarding their experience on a computer. The particular VR equipment used here was the Meta Quest 2, an HMD with an immersive VR level (Meta, 2023). Additionally, before the actual data collection, a pretest was conducted to make sure that the VR environment and questionnaire were comprehensible and worked without any issues. The detailed procedure of the experiment was carried out as follows.

First, every participant was given some VR-related safety instructions (e.g., epilepsy warnings). Next, before putting on the headset, they were shown the controllers and the button placements were explained. Then they put on the headset and followed the verbal instructions on what to press in the virtual interface. As VR devices like the Meta Quest 2 are not commonly used in consumer households, most participants did not have any experience with VR. That is why they were instructed to first complete the pre-installed "First Steps for Quest 2" tutorial[2] in order to understand the controls and how to interact with our VR space which used the same controls. Upon exiting the tutorial, the participants were subsequently instructed to enter the experimental environment, in which they were given the instructions on a user interface. First, they were shown the previously mentioned vignette. Furthermore, some text to better comprehend the current

[2] "First Steps for Quest 2" is the name of the pre-installed tutorial on the Meta Quest 2. It teaches the user the basic controls on how to interact with objects in a virtual environment (Meta, 2023).

situation was added. Next, a short summary was shown in order to make sure that the task of taking pictures was clear. Finally, the explicit controls were shown so that the participants knew how to interact with the environment. The participants then started working on the given task. During this phase, the instructor would talk to the participants if there were any problems or uncertainties regarding the controls. After the participant had informed the instructor that the assignment had been completed, the instructor assisted them in taking the VR equipment off[3]. After that, the participant filled out the follow-up questionnaire about their VR experience.

The text-based survey was based on the same situation, as far as the original vignette (only with changed pronouns) by Homburg (2022) goes. However, it should be noted that in comparison to the VR experiment, no additional text, summary, and controls were provided. The survey, comprised of the vignette and the questionnaire, was then published on the online survey platform "Qualtrics" and distributed among another group of participants. The survey itself contained the exact same questions as the VR questionnaire, with two exceptions: the questions concerning the level of experience regarding VR and the simulator sickness questions were omitted.

VR Experiment Design

The virtual environment was built in the real-time development game engine "Unity" (Version 2021.3.13f1), which is commonly used in research (Menck et al., 2023). The environment was designed with the central characteristics of the original vignette in mind. These key characteristics were a "small urban community ", "big cracks and holes in the road" and the participant "uses [...] social media [...] to post pictures of the holes and cracks in the road [...] under [her] own name" (Homburg, 2022, p. 128). Therefore, the main setting was a long street surrounded by houses and greenery with a partly damaged road. Additionally, the participant was given a smartphone, which was used to take the desired pictures and later post them online. However, since the given vignette was an imaginary scenario with only a short text description and no visual representations, there were many details about the environment that were left up to the reader's interpretation and imagination. That is why many additional elements needed to be implemented in order to make the participants feel like they were actually in the environment depicted. These mainly included static objects (e.g., street requisites like cars, traffic signs, or benches), environmental sounds (e.g., gentle wind sounds, birdsong, music), and other moving non-player characters (NPCs). However, it should be noted that even though the said NPCs were animated, it was not possible to directly interact with them since social presence was not considered in this study. In the VR environment, our intent was to realize the concepts of immersion, presence, and flow in order to show the effects of VR experiments.

To achieve **immersion,** we designed the VR experience with agency, the freedom of self-movement, isolation from the physical environment, perception of self-inclusion, and several types of sensorial feedback in mind. Agency, which describes the control of actions (Freude et al., 2020), was implemented by having various controller buttons to accurately express the users' intentions, offering interactable objects, having hands to interact with these objects, and only using direct interactors[4] to pick up objects. Moreover, all movements and feedback were given in real-time without any time lag. The participant was free to move in a spacious environment through actual physical movement in the real world. In addition, as the VR environment was quite spacious and larger than an indoor room, teleportation was offered as well, so that the whole virtual space could be traversed. The participants were isolated from their physical environment, as their visual perception was limited to the virtual environment. But while being excluded from the real world, they would feel included in the virtual world, because objects would react to the participant's actions, making them feel like a part of the environment. Several types of sensorial feedback were given. When grabbing an object, the participant would hear a sound cue and their controller would vibrate for an instant. For especially important actions, additional cues were provided. When taking a photo

[3] A short showcase video of the VR experience can be found under the following link: https://youtu.be/OKvd1OriMk8.

[4] Having a direct interactor means that the user needs to be physically close to an object in order to interact with it (e.g., to pick it up). Its counterpart would be a ray interactor, which can interact with objects from a distance.

with the smartphone, the participant would hear a camera shutter sound and the smartphone screen would flash white for a short moment to make sure the participant took note of a successful action. Spatial audio was implemented as well. This concept refers to sounds being influenced by spatial features like distance and position (e.g., moving closer to a sound source would increase its perceived volume or the sound source being on your right side would allow your right ear to pick up the sound in a higher volume). For example, there was some birdsong centered around a tree with a bird's nest or music coming from a boombox in the park. Furthermore, visual feedback was given to express permitted actions. For instance, concerning teleportation, the hand ray would change to a white color and show a reticle during selection if the participant was allowed to teleport to the selected spot, while it would stay red if the location was not suitable for teleportation.

Concerning **presence**, we tried to take the combination of multiple sensory modalities, involvement, and embodiment into account. The combination of multiple sensory modalities is similar to appealing to multiple senses by having visual, auditory, and haptic signals. The existence of spatial audio and objects with which the participant could interact played a role as well. The feeling of involvement was achieved by having the participant perform a specific task (taking pictures of road damage) and providing an environment that visually presented aspects relevant to the task (having an actual road with damages and giving the user a phone). We intended for the user to have a feeling of embodiment by giving them virtual hands with the ability to move them and take pictures. We deliberately chose them to have an androgynous look so that every participant, regardless of gender, could vaguely identify with them. The previously mentioned implementation of direct interactors and real-time movements contributed to embodiment as well.

In order to explore the effects of **flow,** we tried to implement enjoyment, the existence of clear goals, and clear immediate feedback. The experience was designed to be enjoyable by offering a number of optional interactive objects (e.g., tennis balls and rackets, empty soda cans, flowers). They were not related to the main task, meaning that the participant was not required to interact with them, but the participant could do so if desired. The possibility of receiving haptic, visual, and auditory interaction feedback might provide a feeling of accomplishment, which can also lead to enjoyment. It was also imperative to provide a clear goal. Upon entering the VR environment, a user interface containing the task would immediately be noticeably displayed in the participant's field of vision to make the goal of the simulation clear right from the beginning. Also, despite the fact that the participant was able to move freely in a spacious setting, the VR environment itself was finite and therefore the participant's movement area was limited by roadblocks to ensure that the participant would not become distracted. Aside from that, the difficulty of the task was set to an appropriate level, so that some physical effort and a basic understanding of the task was needed to complete it, but no expert knowledge in any (academic) field was required. In general, clear and immediate feedback was provided. Aside from the haptic and audio feedback when grabbing objects in general, the phone was a special object that operated in real-time and could be turned on and off. It was a source of additional feedback, e.g., when the camera was turned on and off (a moving screen in contrast to a black screen), and when a photo was taken (sound cue and the phone screen flashing white). Regarding feedback, it was also necessary to distinctly signal task completion. This was achieved by visually blacking out the entire environment after posting the pictures. In this state, only a user interface with the taken pictures was visible so that the user could reflect on the completed task. Lastly, we included some design elements to prevent simulator sickness – a common occurrence when using VR devices. Like motion sickness, simulator sickness refers to sickness symptoms that "originate from elements of visual display and visuo-vestibular interaction" (Kennedy et al., 1993, p. 203). Its symptoms include fatigue, eyestrain, headaches, sweating, etc. (Kennedy et al., 1993). Snap turning[5] and a fade-in were tangibly implemented so that when the participant would load the application, they would slowly fade from the black loading screen to the experimental environment.

[5] Snap turning refers to the ability to turn oneself instantly on the spot in a defined angle. Its converse would be continuous turning, which is known to frequently cause motion sickness (Habgood et al., 2018; Fernandes & Feiner, 2016).

Results

Sample Description and Measures

In the experiment 55 responses (of which 20 belonged to the VR group and 35 to the text-based group) were recorded but not all were usable. This can be attributed to participants not finishing the questionnaire, not accepting the privacy notice regarding data processing, or not passing an attention check. Thus, counting only complete and valid answers, the overall sample size was n = 35, with n = 18 participants in the VR group and n = 17 participants in the text-based group. After experiencing the situation (in VR or as a text-based vignette), every participant filled out a questionnaire regarding their experience. This way immersion, telepresence, flow, and perceived realism could be measured. We used established measurement instruments for the concepts. In Table 1, the concepts, question items, question sources, factor loadings, Cronbach's alpha (α), composite reliability (CR), and average variance extracted (AVE) can be found.

Concepts and Items	Loadings	Scale and Source
Immersion (α = 0.886, CR = 0.916; AVE = 0.749)		7-point Likert scale (Agarwal & Karahanna 2000; Kampling, 2018)
While imagining the scenario, I was able to block out most other distractions.	0.841	
While imagining the scenario, I was absorbed in what I was doing.	0.942	
While imagining the scenario, I was immersed in the tasks that were described.	0.911	
~~While imagining the scenario, I got distracted by other attentions very easily.~~	~~0.591~~	
While imagining the scenario, my attention did not get diverted very easily.	0.757	
Telepresence (α = 0.885, CR = 0.893, AVE = 0.687)		7-point Likert scale (Qiu & Benbasat, 2005; Steuer, 1992)
I forget about my immediate surroundings when I am perceiving the situation.	0.895	
Perceiving the situation often makes me forget where I am.	0.879	
After experiencing the situation, I feel like I come back to the "real world" after a journey.	0.828	
Experiencing the situation creates a new world for me, and this world suddenly disappears when I stop using it.	0.757	
I feel that the situation is more real or present compared to the physical world around me.	0.776	
Flow (α = 0.910, CR = 0.918, AVE = 0.787)		7-point Likert scale (Qiu & Benbasat, 2005; Novak et al., 2000)
~~My imagination is aroused when I perceive the situation.~~	~~0.539~~	
I feel curious when I perceive the situation.	0.840	
Perceiving the situation is interesting.	0.919	
I am absorbed in the situation.	0.891	
It's fun to perceive the situation.	0.896	
Perceived realism (α = 0.890, CR = 0.896, AVE = 0.605)		7-point Likert scale (Slater et al. 2009)
To what extent were there times during the experiment when the experimental situation felt real for you?	0.858	
When you think back about your experience, do you think of the experiment more as images you saw or more as somewhere you visited?	0.686	
During the presentation of the situation, did you often think to yourself that you were just in front of a screen, or did the situation overwhelm you?	0.740	
To what extent can you imagine behaving realistically in the experimental situation as if it was real?	0.809	
How often did you find yourself automatically thinking of realistic behavior within the experimental situation as if it were a real place?	0.738	
How much was your emotional response in the experimental situation as if it had been real?	0.804	
How much were the thoughts you had within the experimental situation the same as if it had been a real situation?	0.795	

~~To what extent were your physical responses (for example, heart rate, blushing, sweating) the same as if it had been a real situation?~~	~~0.591~~	
α = Cronbach's alpha; CR= composite reliability; AVE= average variance extracted		

Table 1. Concepts, Items and Factor Loadings

All concepts were measured on a 7-point Likert scale. Furthermore, it should be noted that only items with loadings > 0.6 were used in the analysis, in accordance with Gefen & Straub (2005). This decision resulted in the data removal of three questions (crossed out in Table 1). The concepts showed sufficient values for CR (> 0.8), Cronbach's alpha (> 0.8), and AVE (> 0.5) considering the thresholds recommended by Urbach and Ahlemann (2010).

Mean Value Comparison

In order to compare the mean values of the two groups with each other, we calculated the mean of each concept for every participant and aggregated these mean values to a single global mean value for each concept in both groups. Additionally, we confirmed normal distribution using the Kolmogorow-Smirnow test (α-Level 0.05) and performed a t-test. The following Table 2 shows the results of the separate mean values for both groups regarding the four investigated concepts and their corresponding standard deviations. These results are additionally visualized in a boxplot diagram (Figure 3).

Concept	**VR (n=18)**		**Text (n=17)**		**t-test (df=33)**	
	Mean	**SD**	**Mean**	**SD**	**t-value**	**p**
Immersion (Agarwal & Karahanna, 2000)	5.472	1.080	4.162	1.272	3.291	0.0024
Telepresence (Qiu & Benbasat, 2005; Steuer, 1992)	4.400	1.286	2.906	1.083	3.706	0.0008
Flow (Qiu & Benbasat, 2005; Novak et al., 2000)	5.861	0.887	3.809	1.086	6.138	< 0.0001
Perceived Realism (Slater et al. 2009)	4.278	1.341	3.294	1.176	2.302	0.0278
SD = standard deviation						

Table 2. Mean and SD Comparison between VR and Text

The immersion in the VR situation was measured at 5.472, while the text-based scenario group only reported an immersion level of 4.162 (Δ = 1.31). Furthermore, the observed telepresence in VR amounts to 4.4, whereas in the text-based vignette, it was measured lower at 2.906 (Δ = 1.494). The most considerable difference (Δ = 2.052) can be observed when examining the flow values. Flow had the highest mean value of the VR group with 5.861 and the second highest value in the text-based group with a mean of 3.809. Lastly, the perceived realism lay at a higher level in VR, with a value of 4.278 in comparison to 3.294, resulting in a difference of Δ = 0.984. Looking at Figure 3, the higher level of the VR mean value became even more noticeable since all VR mean values were higher than their text-based counterparts. All quantiles for the VR group lay at a notably higher level as well. The figure also reveals some outliers in the text-based group. There was one record of an immersion level of 1, which is much lower than the average value of 4.162. Concerning flow, two participants experienced a flow level of 6, contrasting the overall mean value of 2.191 by being 3.809 points higher. With regards to realism, one participant had perceived an average level equal to 6.571, which was 3.277 points higher than the mean of 3.294.

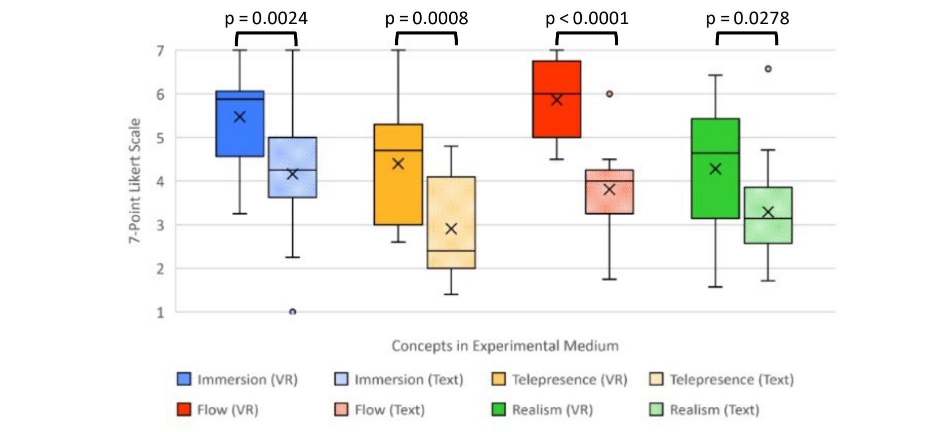

Figure 3. Boxplot Comparison of the Concepts between VR and Text

PLS-SEM

Aside from the mean value comparison, the hypotheses from section 3 of this paper were tested using the partial least squares (PLS) method and SmartPLS 4. We calculated the significance of the path coefficients using a bootstrapping resampling approach with 5000 samples (Benitez et al., 2020; Chin, 1998). The following Figure 4 shows the resulting path coefficients with their corresponding significance levels.

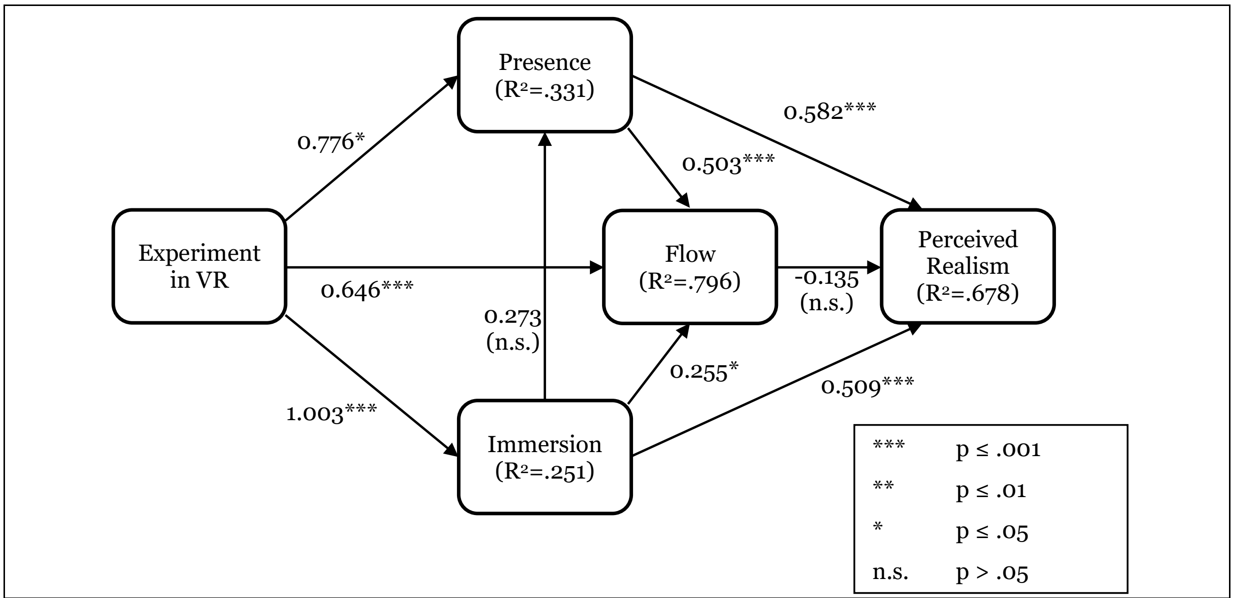

Figure 4. PLS Model with Path Coefficients on the Arrows (β)

The model has a sufficient model fit ($d\_ULS = 2.471 < HI_{95} = 2.542$) and thus allows us to draw further conclusions (Benitez et al., 2020). Our first hypothesis (H1) is supported because the data shows how VR experiments influence immersion (β = 1.003). Likewise, the data demonstrates how VR experiments influence presence (β = 0.776), and thus H2 is supported. H3 is also supported since experiments in VR significantly influence flow (β = 0.646). Summarizing H1 to H3, we were able to show the effects known from the existing literature. Considering our research objective, our results prove that there is a statistically significant effect of immersion on perceived realism (β = 0.509), which supports H4. Furthermore, H5 is also supported, meaning that telepresence significantly influences realism (β = 0.582). However, H6 is not significant (β = -0.135, p = .572), which represents that a significant impact of flow on perceived realism could not be confirmed. The negative path coefficient implies a negative tendency in the correlation of the variables, which is in line with our hypothesis, even if no significance was proven.

Discussion

With our results, we were able to provide statistical evidence that conducting experiments in VR can influence immersion, flow, and (tele)presence during an experiment. Immersion and presence lead to a significantly higher level of perceived realism and there is first evidence that flow might have a negative influence on perceived realism. This was shown through the comparison of mean values for both groups and using PLS-SEM. Therefore, when designing VR experiments with the goal of achieving perceived realism, they should be conceptualized with a high level of immersion and presence. The negative path coefficient from flow to perceived realism implies a negative tendency in the correlation, which is in line with our hypothesis, even if no significance was proven. In the experiment, flow was achieved through optional interaction objects unrelated to the task (e.g., tennis equipment, dancing NPCs). While conducting the experiment, we observed that when presented with these objects, participants would in fact interact with them. For example, in the VR environment, when participants saw the tennis racket and balls, many of them would momentarily stop focusing on their primary task and interact with these items. Thus, we contemplate that having "too much" fun may cause the participant to view the situation too much like a game. This perception may be further reinforced by the participant physically using controllers, which may bring out a mental association with gaming. Accordingly, if a scenario is not viewed as a serious and realistic situation with consequences, unrealistic (or undesirable?) behavior may occur.

Overall, having shown that conducting experiments in VR can lead to a higher level of perceived realism than text-based experiments, we would encourage researchers to consider choosing VR as an experimental medium. However, we are not suggesting that VR is always the right choice of experimental medium, but rather that it should be made use of if the experimental scenario allows it. VR may not be applicable to every vignette, especially when the vignette describes a situation that takes place on a screen. That is why we recommend making the following considerations, based on circumstances that we encountered while conducting this study. First, it should be made sure that the chosen scenario is suitable for VR – meaning that the situation makes use of the advantages of VR, such as its additional modalities. Specifically, situations that require some degree of physical action or situations that would be too dangerous to investigate in real life (Jones et al., 2022), would be particularly suitable. We motivate researchers to call this kind of experiment a "beyond-screen experiment". Also, the higher effort of data collection must not be underestimated. There is a considerable difference in the time and effort needed for recording a participant's data, depending on the medium. In our experience, a full run-through for a single VR participant can take up to 45 minutes. These circumstances make it far more time-consuming to conduct a VR experiment to conduct a text-based online survey, which can be answered anywhere, at any time, and can easily be distributed (Karahanna et al., 2018). Remote VR experiments with experienced VR users could be used to tackle this issue (Radiah et al., 2021). Limitations of our study might be the measurement of presence in a real-world setting (Machemehl, 2022) and the use of non-VR questionnaires (Wagener et al., 2020). Additionally, we only used one representative vignette for both the text and VR-based vignettes and had a limited sample size. Future research could delve into the details of text vignettes and especially VR vignettes and their role in the creation of perceived realism.

Conclusion

Since experiments are an essential aspect of science and research, it is important to conduct them effectively – ideally with a high level of internal and external validity as well as realism. However, choosing one of these variables over the other cannot seem to be avoided, which leads to certain trade-offs. This may further lead to a lack of realism in experiments, even though realism is a very important factor that ensures that the results of the experiments can be applied to practice. To address this issue, we have investigated the possibility of using VR technologies to achieve a more realistic experimental setting in comparison to traditional text-based experiments. After recreating a vignette study in two settings (as a virtual environment and as a text-based study) we can provide evidence that VR experiments might be an interesting (and sometimes superior?) tool for experimental studies as they increase perceived realism. We provide deeper insights into how perceived realism is created in experiments. This leads to the following credo for designing VR experiments: increase presence and immersion while not making the flow unnecessarily high by adding extra game-like elements.

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