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Virtual reality technology and game enjoyment: The contributions of natural mapping and need satisfaction☆

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ABSTRACT

Based on self-determination theory, the current laboratory experiment investigates how the use of virtual reality (VR) technology shapes the gaming experience. We hypothesize that playing the VR version offers a more naturally mapped playing experience than playing the non-VR version of the same game. Further, we assume that natural mapping is positively related to autonomy and competence need satisfaction, which in turn will predict higher levels of game enjoyment. One hundred thirty-three participants either played the non-VR or the VR version of the game *The Elder Scrolls V: Skyrim*. We found that playing the VR version induced higher levels of game enjoyment than playing the non-VR version. Path analysis affirmed our assumption that VR technology can increase game enjoyment via natural mapping and the resulting satisfaction of competence and autonomy needs. Implications of these findings for games research and game design are discussed.

1. Introduction

With the introduction of affordable virtual reality (VR) systems like the Oculus Rift and the HTC VIVE, VR technology has gained much attention. Sales numbers have increased significantly and worldwide revenue is expected to more than double between 2018 and 2023 (Superdata, 2020). Further, a growing number of users are integrating VR into their lives: For instance, in the US, 60.8 million active users are expected by 2022 (up from 34.6 million in 2018; Petrock, 2020). Data from Germany (where the current study was conducted) indicates that 17% of people older than 16 years already use VR devices, and an additional 41% are planning to (or willing to) use VR in the future (Klöß, 2021). The sales volume of VR hardware and content in Germany is expected to exceed half a billion Euro in 2024, which would represent more than a triple increase compared to 2019 (Deloitte, 2020).

While VR technology is utilized in a wide variety of contexts ranging from education (Bailenson et al., 2008) and therapy (Gonçalves et al., 2012) to engineering training (Wang et al., 2018), most consumers use VR for entertainment. According to representative survey data from Germany, watching movies (56%) and concerts (39%), or going on virtual vacation (71%) are among the most popular activities VR users engage in. However, the most important field of application of VR devices is gaming (77%; Klöß, 2021), which also makes up to 43% of VR's global income in 2018 (Viar360, 2019). The industry sees great potential for the application of VR technologies in gaming and speaks of a 'mega trend' in this context (Bitkom – Bundesverband Informationswirtschaft, 2017).

Indeed, first empirical studies fuel hopes that VR devices may revolutionize the way we play digital games and experience virtual worlds. For example, it was found that playing in VR can lead to a more interesting and satisfying gaming experience (e.g. Peng et al., 2019), to increased feelings of presence in the virtual environment (e.g. Pallavicini et al., 2019) and, in general, to greater enjoyment (e.g. Shelstad et al., 2017). However, existing studies often lack a clear theoretical foundation and fall short in explaining underlying mechanisms of an entertaining VR gaming experience.

A greater understanding of what makes VR games enjoyable and of how using VR devices changes the gaming experience in comparison to traditional computer and video games is important for several reasons. Identifying determinants of the fascination of VR gaming, of course, is of high interest for the industry. Precisely identifying what users appreciate when using VR devices offers the opportunity to systematically

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work on improving particular aspects of the user experience.

Gaming in general is a very popular leisure time activity worldwide. Computer and video games are often used for recreational purposes and several studies have found that playing can have very positive effects. For example, it can contribute to stress reduction and recovery (e.g. Reinecke, 2009a, 2009b), mood repair (e.g. Bowman & Tamborini, 2012; Reinecke et al., 2012; Rieger et al., 2015), or increases in eudaimonic and hedonic well-being (e.g. Reer & Quandt, 2020). VR gaming could possibly further improve these positive aspects and to understand in more detail what makes VR gaming enjoyable and how it differs from non-VR gaming may be an important first step to better assess and uncover these potentials.

The present study aims to supplement previous works and examine psychological mechanisms relevant for the enjoyment of playing VR games. To do so, self-determination theory (SDT) is applied to the context of VR gaming. SDT is a psychological theory of motivation that explains pleasure and well-being on the basis of the satisfaction of fundamental human needs (e.g. Deci & Ryan, 2000; Ryan & Deci, 2000). In recent years, SDT has developed into one of the most established theories in media entertainment research and has frequently served as a framework in laboratory experiments and survey studies on the uses and effects of conventional computer and video games (e.g. Reer & Krämer, 2020a, 2020b; Ryan et al., 2006; Tamborini et al., 2010).

Based on existing works and theoretical considerations, we argue that SDT and its need satisfaction paradigm are particularly well-suited for an application to the context of VR gaming. In the following, we present a laboratory experiment rooted in SDT that aims to contribute to a deeper understanding of the fascination of VR gaming and its underlying factors.

1.1. Enjoyment of virtual reality games

As stated above, an increasing number of studies has investigated whether using VR technology may lead to an improved gaming experience in comparison to traditional desktop gaming. For example, Shelstad et al. (2017) conducted a laboratory experiment in which participants played the video game *Defense Grid 2*, one time using an Oculus Rift VR headset, and another time using a conventional computer monitor. They found that the graphics and sound quality of the VR version were evaluated more positively than the desktop version. Further, playing in VR led to higher levels of overall satisfaction and to more enjoyment in comparison to playing the classical game version.

In a similar experiment, Peng et al. (2019) found that playing the game *A Show of Kindness* using a VR device induced stronger positive feelings like interest, contentment, and happiness than playing the same game using traditional display technology. Pallavicini et al. conducted a series of studies and found that VR gaming was perceived as more pleasant than non-VR gaming and, for example, elicited more positive affect, happiness, flow, and surprise (Pallavicini et al., 2018, 2019; Pallavicini & Pepe, 2019).

Even though it is quite well documented that the use of VR technology in general can positively influence the gaming experience, the factors or mechanisms contributing to the enjoyment of playing VR games remained understudied.

Two concepts that were considered to be relevant in this context are immersion (Jennett et al., 2008), and presence (also referred to as telepresence, e.g. Steuer, 1992). Immersion describes a state of high cognitive involvement in a media environment (e.g. Jennett et al., 2008), while presence refers to the feeling of being physically located in the virtual world rather than in the real word (Steuer, 1992; Sanders & Cairns, 2010). Several studies have shown that playing in VR can increase feelings of presence and immersion (e.g. Pallavicini et al., 2019, 2018; Pallavicini & Pepe, 2019; Peng et al., 2019), and some studies found that presence and immersion positively predicted game enjoyment (e.g. Ijaz et al., 2020; Klimmt et al., 2018; Shafer et al., 2019). However, one should be aware that presence and immersion are not per definition and under all circumstances positive experiences. For example, Hartmann and Fox (2021) argue that using VR devices for entertainment purposes (like gaming) may induce such a realistic and immersive experience that cognitive distancing, reappraisal, and affect regulation may be threatened. Thus, not only positive feelings like enjoyment, happiness, and positive affect may be amplified, but also negative emotions like distress, nervousness, discomfort, or shame (e.g. Lavoie et al., 2021).

Given the limited knowledge on the underlying psychological mechanisms of a pleasant VR gaming experience, there is a high need for more theory-driven research. We believe that SDT may be a concept that could be useful in providing a deeper understanding of the enjoyment of playing VR games. SDT will be explained in detail in the next paragraphs.

1.2. Self-determination theory and game enjoyment

SDT was developed by Ryan and Deci as a general theory of human motivation and psychological functioning (e.g. Deci & Ryan, 2000; Ryan & Deci, 2000). One of the central assumptions of SDT is the existence of three innate psychological human needs: competence, relatedness, and autonomy. Competence relates to self-efficacy and the desire to reach valuable goals, relatedness refers to the desire for love and meaningful relationships, and autonomy relates to the desire for self-actualization and freedom of choice (Deci & Ryan, 2000). According to SDT, the wish to satisfy these needs is an important motivator of human behavior and successful need satisfaction is a prerequisite for psychological well-being and mental health. Further, activities that offer possibilities to satisfy autonomy, competence, and relatedness have a high intrinsic motivation and are perceived as pleasant and enjoyable (Deci & Ryan, 2000; Ryan & Deci, 2000).

These general postulates of SDT have been supported by many empirical studies across diverse life domains (Deci & Ryan, 2008). For example, it was found that successful need satisfaction in the context of sports and exercise contributes to well-being, enjoyment, and motivation (e.g. Puente & Anshel, 2010; Quested et al., 2013). Further, the satisfaction of autonomy, competence, and relatedness needs was identified as a factor that can positively influence the mental health of people living in nursing homes (Custers et al., 2010; Kasser & Ryan, 1999), or the performance and well-being in working contexts (Baard et al., 2004; Deci et al., 2001).

In recent years, several studies have used SDT as a framework to investigate the motivation and enjoyment of playing digital games (e.g. Ryan et al., 2006; Reer & Krämer, 2020a; Reinecke et al., 2012; Rieger et al., 2014; Tamborini et al., 2010). The idea underlying this approach is that digital games should be particularly well suited to satisfy competence, relatedness, and autonomy needs (Przybylski et al., 2010; Reer & Quandt, 2020). Games offer a high freedom of choice and allow to try out things that are impossible in real life, thus satisfying autonomy needs. Further, experiencing self-efficacy and success in games can satisfy competence needs. And finally, the possibilities many games offer in terms of playing together and interacting with fellow players can serve as a source for the satisfaction of the need for relatedness (Przybylski et al., 2010; Reer & Quandt, 2020).

Indeed, several empirical studies have confirmed these assumptions and found that playing digital games can satisfy the three needs postulated in SDT and that successful need satisfaction in the gaming environment positively predicted game enjoyment, increases in mood and other indicators of well-being, as well as the motivation for future play (Przybylski, Ryan, & Rigby, 2009; Reer & Krämer, 2020a; Reinecke et al., 2012; Rieger et al., 2014; Ryan et al., 2006; Tamborini et al., 2010).

Some studies have additionally identified particular underlying factors that are relevant for successful need satisfaction in gaming contexts (e.g. Reer & Krämer, 2018, 2020a; Reinecke et al., 2012; Tamborini et al., 2010, 2011). For example, the presence of human

co-players, cooperative team play, and the engagement in game-related groups, like clans and guilds, were found to foster the satisfaction of the need for relatedness (Reer & Krämer, 2018, 2020a; Tamborini et al., 2010).

An important concept in understanding the game-based satisfaction of the needs for autonomy and competence is natural mapping. Natural mapping refers to the level of realism and naturalness an interface provides (Skalski et al., 2011). The more the actions within the gaming environment match the actions required to do the same thing in the physical world, the higher the level of natural mapping experienced by the players (Skalski et al., 2011).

Tamborini et al. (2010) conducted a laboratory experiment with 129 participants that played the bowling simulation game *Brunswick Pro Bowling*. They demonstrated that natural mapping increases the levels of autonomy and competence experienced while playing, resulting in increases in game enjoyment.

1.3. Virtual reality games, natural mapping, and need satisfaction

Skalski et al. (2011) introduced a typology describing four different types of gaming controllers that vary in the levels of naturalness they provide. *Directional natural mapping* (1) refers to classical game controllers that are expected to induce relatively low levels of perceived naturalness, like a joystick or a gamepad. Moving the joystick upwards or pressing the left button on a gamepad causes the in-game character to move in the respective direction. *Kinesic natural mapping* (2) refers to camera-based systems, like the Sony EyeToy, that record the natural body movements of the players and transfer them to the virtual environment. These systems are perceived as fairly natural, but they lack the "tangible stimulation of being in contact with a real-life object" (Skalski et al., 2011, p. 228). *Incomplete tangible natural mapping* (3) refers to motion controller systems, like PlayStation Move or Nintendo Wii. These setups capture the natural arm or hand movements of the players via a tangible controller, but the controllers differ in the shape and weight compared to the object they represent (e.g. a bowling ball in a bowling simulation or bow and arrow in a hunting game). Finally, *realistic tangible natural mapping* (4) refers to controllers that aim to mimic the object they represent in the virtual word, like steering wheels used to drive cars in a racing game or gun controllers used in a shooter game. These devices potentially provide the most realistic experience and the highest levels of natural mapping. They are often used in amusement arcades, but are less common in private settings.

Falling into the category of (incomplete) tangible natural mapping, the Nintendo Wii with its motion controllers was one of the first commercial mass-market gaming consoles that implemented a potentially more naturally mapped controller system for home use. However, some studies indicated that these early motion capture technologies were not sufficiently mature and that some players even evaluated them as less natural than traditional game controllers (e.g. Bowman et al., 2017; Tamborini et al., 2010).

Current VR systems like the Oculus Rift or the HTC VIVE combine a new generation of motion controllers with a 360-degree head-mounted display (HMD) that process the user's natural hand and head movements. According to Skalski et al.'s (2011) typology, this hardware setup could be described as a mixture of (incomplete) tangible mapping (VR controllers) and kinesic mapping (tracking of head movements and body position via HMD), promising a highly realistic and naturally mapped user experience.

There is indeed empirical evidence indicating that especially the use of a VR HMD can have positive effects on perceptions of natural mapping. For example, Seibert and Shafer (2018) found that participants that played *Half Life 2* using an Oculus Rift HMD reported higher levels of perceived natural mapping than participants that played the game using an HD television display. Similarly, Wu and Lin (2018) found that watching a 360-degree gameplay video using an HTC VIVE VR system induced stronger feelings of natural mapping than watching the same video using a tablet or a desktop computer.

Putting these findings in the context of SDT, it seems very plausible that the more naturally mapped experience VR systems can provide will increase feelings of competence and autonomy perceived while playing, which, in turn, will increase game enjoyment.

So far, only very few empirical studies have taken an SDT approach on the user experience VR systems provide. Kosa et al. (2020) conducted an online survey among individuals that at least once had used a VR game in the past. The questionnaire measured concepts like immersion, concentration, and enjoyment and additionally included instruments on autonomy and competence need satisfaction experienced while using VR games. It was found that VR games in general can satisfy autonomy and competence needs and that successful need satisfaction (in line with the assumptions of SDT) was positively related to increases in enjoyment and technology acceptance. However, these results were solely based on a retrospective evaluation of past VR experiences and were not confirmed by a laboratory experiment.

An experiment on VR and need satisfaction was conducted by Ijaz et al. (2020). They compared the user experience induced by an open world vs. a static variant of a VR exergame. It was found that autonomy need satisfaction positively predicted enjoyment in both experimental conditions. In the open world variant, autonomy additionally predicted future play intentions and positive affect. However, the study did not provide a comparison between a VR and a non-VR version of the game. Thus, it remains unclear whether VR games are more effective in inducing need satisfaction than non-VR games, and whether need satisfaction is a relevant factor in explaining the unique user experience and enjoyment of VR games.

Pallavicini and Pepe (2019) conducted an experiment comparing the VR and non-VR versions of the racing game *Driveclub*. Despite the study following a rather explorative approach and not being strictly based on SDT, it included a measurement of in-game competence. Playing the game using a PlayStation VR headset induced slightly higher levels of competence than using a conventional TV display. However, the difference did not reach significance. Notably, a limitation of the study concerns the fact that no naturally mapped VR motion controller was used. While the display type varied across the two experimental conditions (VR headset vs. conventional display), players always used a standard PlayStation gamepad.

In the current study, we conducted a laboratory experiment to systematically compare VR gaming (VR headset and VR motion controllers) and non-VR gaming (conventional display and conventional controls). We believe that natural mapping and SDT are two key concepts in helping to understand how newly introduced VR systems shape the gaming experience. Our central assumption is that playing the VR version offers a more naturally mapped playing experience than playing the non-VR version of the same game. In line with the existing literature, we further suppose that natural mapping is positively related to autonomy and competence need satisfaction, which, in turn, will predict higher levels of game enjoyment. Based on these assumptions, a path model was hypothesized (see Fig. 1) that will be explained in detail in the next section.

1.4. Research questions and hypotheses

Several studies have shown that using current VR devices can have positive effects on the gaming experience and, for example, can lead to increased levels of interest, happiness, flow, or game enjoyment (Pallavicini et al., 2018, 2019; Pallavicini & Pepe, 2019; Peng et al., 2019; Shelstad et al., 2017). Aiming at replicating these findings, we hypothesize that playing the VR version using an HTC VIVE VR system (as one of the currently established VR devices) will induce higher levels of game enjoyment than playing the same game using traditional game controls and a monitor display.

H1. *Playing in VR leads to higher levels of game enjoyment than playing the*

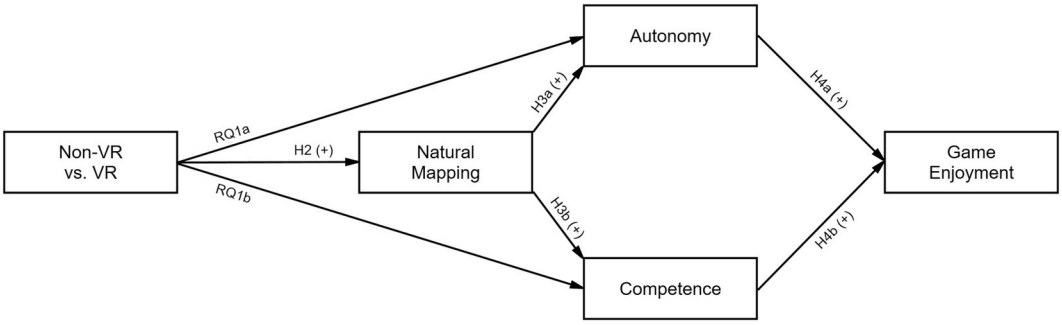

Fig. 1. Visualization of the predicted path model with hypotheses and research questions.

non-VR version of the same game.

The central aim of our study is to provide a greater understanding of the positive effects using VR devices can have on the gaming experience. The path model shown in Fig. 1 subsumes our SDT-based assumptions.

VR systems automatically capture players' natural head movements and the computer-generated surroundings are rendered accordingly, thus providing a much more realistic and intuitive perception of the virtual world than conventional computer displays. Further, a new generation of motion controllers offers the possibility to interact with the gaming world much more naturally than pressing buttons on a keyboard or a gamepad. Our second hypothesis therefore is that playing a game using a VR device is perceived as more natural than playing the same game using a traditional display and traditional game controls.

H2. *Playing the VR version is related to higher levels of perceived natural mapping than playing the non-VR version of the same game.*

Similar to several previous studies (e.g. Przybylski, Ryan, & Rigby, 2009; Reinecke et al., 2012; Rieger et al., 2014; Tamborini et al., 2011), the current study will focus on a single-player situation and thus will not consider relatedness need satisfaction. Tamborini et al. (2010) have shown that natural mapping is an important underlying factor of competence and autonomy experienced when playing traditional digital games.

H3a. **:** *Perceived natural mapping will be positively related to increased levels of the satisfaction of autonomy needs.*

H3b. **:** *Perceived natural mapping will be positively related to increased levels of the satisfaction of competence needs.*

Additional direct effects playing the VR version of the game may have on need satisfaction will also be considered in order to examine whether natural mapping fully or partially mediates this relationship.

RQ1a. **:** *Is playing the VR version of the game (when contrasted to playing the non-VR version) directly related to autonomy need satisfaction?*

RQ1b. **:** *Is playing the VR version of the game (when contrasted to playing the non-VR version) directly related to competence need satisfaction?*

In line with the assumptions of SDT and based on existing studies on non-VR games (e.g. Reer & Krämer, 2020a; Rieger et al., 2014; Tamborini et al., 2010), we assume that need satisfaction is positively related to game enjoyment.

H4a. **:** *Autonomy need satisfaction is positively related to increased levels of game enjoyment.*

H4b. **:** *Competence need satisfaction is positively related to increased levels of game enjoyment.*

Finally, we expect that natural mapping and need satisfaction can explain the link between using the VR version of the game and increased levels of game enjoyment. In other words, we expect to identify a significant positive indirect effect.

H5. **:** *The indirect path from playing the VR version of the game (when contrasted to playing the non-VR version) to game enjoyment (via natural mapping and need satisfaction) is significant and positive.*

2. Material and methods

2.1. Sample, stimulus, and procedure

The sample for the current analysis consists of 133 individuals (93.2% students; 50.4% females; mean age: 24 years, $SD = 3.97$) who were recruited to participate in a laboratory experiment conducted at a large German university.[1] The participants were invited to the lab to play the role-playing game *The Elder Scrolls V: Skyrim* (for 7 min after a 3-min training phase). The playing instruction was to hunt animals to provide food for one's family. The task resembled a typical playing situation in this kind of game and made it necessary to use bow and arrow and to move around in the gaming environment.

Before playing the game, participants were informed about the procedures, signed a consent agreement, and filled in a pre-play questionnaire containing questions for later randomization checks. The experiment followed a between-subjects design. Participants assigned to condition one (classical desktop gaming) played the standard version of the game using a 24-inch flat screen and keyboard/mouse controls ($n = 65$). In condition two (VR gaming), participants played the VR version of the game using an HTC VIVE VR system with a 360-degree headset and VR motion controllers ($n = 68$). After playing, the participants filled in a post-play questionnaire, were debriefed, and received a participation compensation of 10 Euro.

2.2. Measurements

The measurements used in the current study were based on previous works. Some instruments had to be translated to German. The translations were created in cooperation with a professional translation service to ensure equivalence of meaning. The reliability of the measurements was tested by calculating Cronbach's Alpha. Because the suitability of Cronbach's Alpha has recently been called into question by some methodologists (e.g. Dunn et al., 2014; Hayes & Coutts, 2020; McNeish, 2018), we additionally calculated McDonald's Omega for each scale (using Hayes's Omega macro for SPSS; see: Hayes & Coutts, 2020). Scores for all scales were built by summing up and averaging the corresponding items.

2.2.1. Natural mapping

The 6-item natural mapping scale developed by Skalski et al. (2011)

[1] The data used in this analysis were collected as part of a larger experiment that included a third experimental condition (VR treadmill) and some additional user experience variables out of the scope of the present analysis. For more information see: Wehden et al. (2021)

was used to measure how natural and realistic the participants perceived the gaming experience (e.g. 'The actions used to control the game seemed natural.'). As suggested by the authors of the instrument, a 7-point scale ranging from 1 = 'strongly disagree' to 7 = 'strongly agree' was used to rate the items. Calculating the Cronbach's Alpha and McDonald's Omega values indicated a good reliability of the instrument ($M = 3.97$, $SD = 1.45$, $\alpha = 0.917$; $\omega = 0.918$).

2.2.2. Need satisfaction

The Player Experience of Need Satisfaction (PENS) scale by Ryan et al. (2006) was used to measure autonomy and competence experienced while playing. Three items addressed autonomy (e.g. 'I experienced a lot of freedom in the game.') and 3 items addressed competence (e.g. 'I felt very capable and effective when playing.'). The items were rated on a scale ranging from 1 = 'strongly disagree' to 5 = 'strongly agree' (autonomy: $M = 3.13$, $SD = 0.95$, $\alpha = 0.738$, $\omega = 0.760$; competence: $M = 2.72$, $SD = 0.91$, $\alpha = 0.758$, $\omega = 0.780$).

2.2.3. Game enjoyment

Following the approach of Tamborini et al. (2010) and others (e.g. Reer & Krämer, 2020a; Reinecke et al., 2012; Rieger et al., 2014), we measured game enjoyment using items adopted from the interest/enjoyment subscale of the Intrinsic Motivation Inventory (Ryan, 1982; Ryan et al., 1983). Six items (e.g. 'I enjoyed playing this game very much.') were rated on a scale ranging from 1 = 'strongly disagree' to 7 = 'strongly agree' ($M = 4.96$, $SD = 1.65$, $\alpha = 0.956$, $\omega = 0.958$).

2.2.4. Previous VR experiences and playing skills

Previous studies have shown that playing skills can influence game enjoyment and in-game need satisfaction (e.g. Reer & Krämer, 2020a; Tamborini et al., 2010). Thus, the playing skills of the participants were considered a relevant additional variable in the current study. Four items were adopted from the German version (Pietschmann, 2014) of the playing skill scale by Bracken and Skalski (2006). An example item is: 'I am a very good computer game player.' The participants rated the items on a scale ranging from 1 = 'strongly disagree' to 5 = 'strongly agree' ($M = 2.59$, $SD = 1.03$, $\alpha = 0.897$, $\omega = 0.901$).

To assess how experienced the participants were in using VR technology, they were asked to rate their VR experience level using a single item measure (1 = 'completely inexperienced' to 5 = 'very experienced'; $M = 1.88$, $SD = 0.91$).

Additionally, participants were asked how many hours per week they normally spend playing digital games ($M = 4.58$, $SD = 6.91$).

3. Results

Before conducting the main analyses, we first calculated several randomization checks. We found that the two experimental conditions did not differ significantly concerning age (t (131) = 1.49, $p = .138$), gender (χ^2 (1) = 0.008, $p = .929$), and previous experiences with VR technology (t (131) = –0.608, $p = .544$). There were also no significant differences concerning playing time per week (t (131) = 0.009, $p = .993$) and playing skill (t (131) = –0.691, $p = .491$) between the VR and the non-VR group.

3.1. Main analyses

Conducting an independent t-test revealed that the VR version of the game ($M = 5.37$, $SD = 1.60$) was perceived more enjoyable (t (131) = –2.97, $p < .01$, $d = –0.52$) than the non-VR version ($M = 4.54$; $SD = 1.62$). Thus, hypothesis H1 was supported.

3.1.1. Path model

Path analysis using SPSS Amos software package (maximum likelihood estimation) was conducted to test the predicted model. A preliminary inspection of the zero-order correlations revealed a significant relationship between autonomy and competence need satisfaction (see Table 1). The corresponding error terms were thus allowed to co-vary in the model. Playing skills were found to be positively correlated with competence need satisfaction and game enjoyment. Since it is very plausible that more skilled players experience more competence and enjoyment while playing, playing skill was added as a predictor of these two variables. The experimental condition was coded with 0 = non-VR and 1 = VR. The estimated model is shown in Fig. 2.

Univariate and multivariate normality were inspected based on the recommendations of Byrne (2010) and Kline (2011): The absolute values for skewness (< 3.0; Kline, 2011), kurtosis (< 7.0, Byrne, 2010), and multivariate kurtosis (Mardia's normalized estimate < 5.0; Byrne, 2010) all lay below the recommended thresholds, indicating no substantial deviations from normality. The data was additionally screened for multivariate outliers based on Mahalanobis distance (D^2). Applying a conservative criterion ($p < .001$) as recommended by Kline (2011), no outliers were identified.

Model fit was examined based on established fit criteria (Byrne, 2010; Hu & Bentler, 1999): Comparative Fit Index (CFI) > 0.95, Standardized Root Mean Square Residual (SRMR) < 0.08, and Root Mean Square Error of Approximation (RMSEA) < 0.06. The tested model showed a good fit to the data (see Fig. 2).

Affirming hypothesis H2, playing the VR version of Skyrim induced higher levels of natural mapping than playing the non-VR version of the game ($\beta = 0.55$, $p < .001$). Natural mapping was positively related to autonomy ($\beta = 0.41$, $p < .001$) and competence ($\beta = 0.46$, $p < .001$) need satisfaction, thus hypotheses H3a and H3b were confirmed.

RQ1a and RQ1b aimed at investigating whether there are additional direct effects of playing in VR on need satisfaction. We found that playing in VR had a small additional direct effect on autonomy need satisfaction ($\beta = 0.19$, $p < .05$). When controlled for playing skills and natural mapping, playing in VR showed a small negative direct effect on competence need satisfaction ($\beta = -0.20$, $p < .05$).

In line with hypotheses H4a and H4b, autonomy ($\beta = 0.50$, $p < .001$) and competence ($\beta = 0.24$, $p < .001$) both had unique positive effects on game enjoyment.

Further, participants' playing skills were found to be positively related to competence need satisfaction ($\beta = 0.35$, $p < .001$) and game enjoyment ($\beta = 0.17$, $p < .05$).

SPSS Amos provides bootstrapping to test the significance of indirect paths. The indirect effect hypothesized in H5 was tested based on 5,000 bootstrapping samples (95% bias-corrected confidence intervals). Confirming H5, we detected a significant positive indirect path from playing the VR version of the game to game enjoyment via natural mapping and need satisfaction ($\beta = 0.22$ [0.11, 0.34], $p < .001$).

4. Discussion

VR is one of the most important current trends in the field of digital gaming (Bitkom – Bundesverband Informationswirtschaft, 2017). Several studies have shown that playing in VR can make gaming more interesting, can induce positive feelings, like happiness and contentment, and is perceived as more satisfying and enjoyable than traditional desktop gaming (Pallavicini et al., 2019; Peng et al., 2019; Shelstad et al., 2017). However, despite these promising findings, the psychological mechanisms that contribute to a pleasant VR gaming experience remained understudied. Existing empirical works often explained the attractiveness of VR games by heightened levels of presence and immersion (e.g. Klimmt et al., 2018; Shafer et al., 2019). We argue that explaining the enjoyment of VR games by these concepts has its limitations, since immersion and presence are not under all circumstances perceived as positive (Hartmann & Fox, 2021; Lavoie et al., 2021). We therefore aimed to find alternative explanations to deepen the understanding of the psychological mechanisms underlying a pleasant VR gaming experience.

SDT served as the theoretical foundation for the current study. Based

Table 1
Means, standard deviations and Pearson correlations.

	M	*SD*	1	2	3	4	5	6
1. Non-VR (0) vs. VR (1)	–	–	–					
2. Playing skill	2.59	1.03	.060	–				
3. Natural mapping	3.97	1.45	.549**	-.041	–			
4. Competence	2.72	.91	.073	.334**	.335**	–		
5. Autonomy	3.13	.95	.416**	.032	.515**	.349**	–	
6. Enjoyment	4.96	1.65	.251**	.264**	.377**	.469**	.591**	–

**p < .01
*p < .05

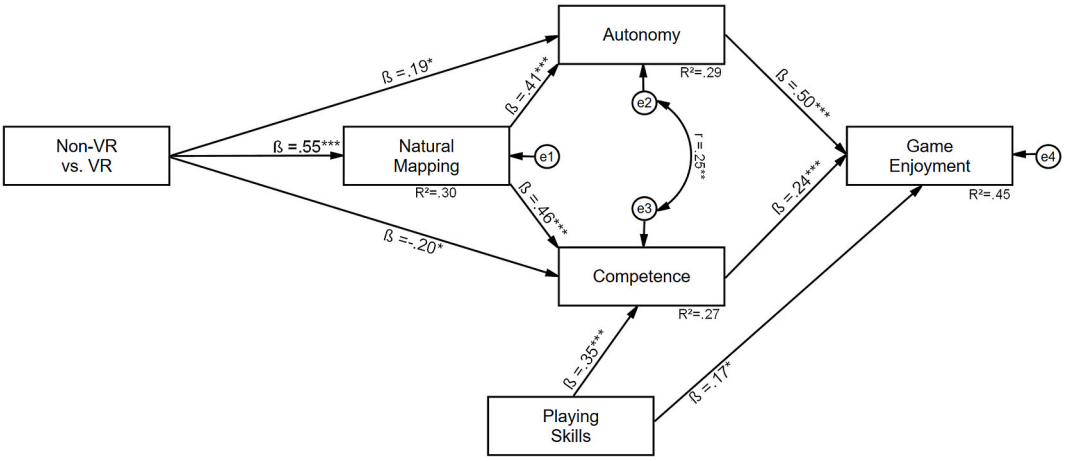

Fig. 2. Estimated model showing standardized path weights. * $p < .05$, ** $p < .01$, *** $p < .001$. Model fit: $\chi^2 = 2.52$, $df = 5$, $p = .774$; CFI = 1.0; SRMR = .021; RMSEA = .000 (90% CI: .000, .081).

on previous studies (e.g. Ijaz et al., 2020; Kosa et al., 2020; Ryan et al., 2006; Tamborini et al., 2010), we argue that the perceived naturalness of the playing experience and the satisfaction of the needs for autonomy and competence could play a central role in the enjoyment of playing VR games. To confirm this assumption, a laboratory experiment was conducted, contrasting the VR and the non-VR version of the role-playing game Skyrim.

In line with previous works and our expectations, VR technology provided a significantly more enjoyable playing experience than traditional display and controller technology. Natural mapping was identified as a central variable in this context. Playing the VR version of Skyrim was perceived as more realistic and natural than playing the non-VR version. Confirming the findings of Tamborini et al. (2010), natural mapping positively predicted autonomy and competence need satisfaction; and in line with the assumptions of SDT and studies on traditional computer games (e.g. Przybylski, Ryan, & Rigby, 2009; Ryan et al., 2006; Tamborini et al., 2010), both autonomy and competence experienced while playing significantly contributed to game enjoyment. Inspecting the indirect paths substantiated our assumption that using VR technology can increase game enjoyment via natural mapping and the resulting satisfaction of competence and autonomy needs.

These findings have several implications. First, they emphasize the importance of considering additional factors and theories in developing our understanding of the user experience in VR technology. Previous works by Kosa et al. (2020) and Ijaz et al. (2020) have suggested a general relevance of need satisfaction in explaining the enjoyment of VR games. Our study further confirms these findings based on a laboratory experiment and a systematic comparison between playing the VR vs. non-VR version of a popular commercial role-playing game. Furthermore, natural mapping was identified as a central underlying mechanism of autonomy and competence need satisfaction in VR gaming. Thus, natural mapping and need satisfaction should be considered in future studies on VR gaming.

For the industry, our results can serve as a basis for the improvement of VR hardware and software. According to our results, one central aim of game designers should be to further improve the naturalness of the VR experience. The more naturally mapped the interface is designed, the more need satisfaction is experienced, which in turns makes the VR experience more enjoyable. Notably, recent studies have shown that perceived enjoyment is an important factor for the acceptance of VR technology, even more important than perceived usefulness (Lee et al., 2019).

In a broader context, our findings suggest some promising directions for future research on the positive psychological effects of gaming. An increasing number of studies has examined digital games' impacts on stress reduction and recovery (e.g. Reinecke, 2009a, 2009b), mood repair (e.g. Bowman & Tamborini, 2012; Reinecke et al., 2012; Rieger et al., 2015), or well-being (e.g. Reer & Quandt, 2020). Previous works have indicated that need satisfaction can be a relevant underlying factor for several of these valuable outcomes (Reer & Krämer, 2020a; Reinecke et al., 2012; Ryan et al., 2006). In light of our results, it seems plausible that VR gaming may not only be more enjoyable than traditional gaming, but could also have a higher potential for the induction of other desirable outcomes, like recreation, stress reduction, or increasing well-being.

On the other hand, the higher attractiveness of VR games and the increased possibilities to satisfy autonomy and competence needs may also carry a certain risk of misuse. The addictiveness of digital games is currently under a lively debate among scholars (e.g. Aarseth et al., 2017; Rumpf et al., 2018) and studies have shown that at least a small percentage of players indeed develop disordered usage patterns and have problems controlling their gaming behaviors (e.g. Reer et al., 2021; Wittek et al., 2016). There is evidence that need satisfaction may play a role here. For example, it was found that psychological need satisfaction experienced in the context of gaming predicted more time spend playing and an increased engagement in gaming-related activities (Reer &

Krämer, 2020b; Ryan et al., 2006). Especially, players with deficits in satisfying their needs for competence, autonomy, and relatedness in their daily lives were found to be at risk for the development of pathological forms of game engagement (Allen & Anderson, 2018; Przybylski, Weinstein, et al., 2009; Reer & Krämer, 2020b). Thus, for players that use games in a compensatory, escapist manner, the increased opportunities VR games offer in terms of need satisfaction may not only be particularly attractive, but may also constitute an increased risk. There are already first discussions whether the immersiveness of VR technology may increase the 'addictive' potential of games (e.g. Stavropoulos et al., 2019). However, need satisfaction has (to the best of our knowledge) not yet been considered a relevant factor in this context.

4.1. Limitations and future steps

In the current analysis, we contrasted the traditional gaming situation (flat-screen display and keyboard/mouse controls) with the typical VR playing situation (360-degree HMD and motion controllers). Natural mapping experienced when playing the VR version of the game was thus understood as a result of both – the use of the headset and the controllers. Previous research has shown that the tracking of the players' head movements via a VR HMD increases natural mapping (Seibert & Shafer, 2018; Wu & Lin, 2018), while results for some early motion controller systems were less clear (e.g. Seibert & Shafer, 2018; Tamborini et al., 2010). Future research should therefore examine in more detail which of the components of current VR systems has a stronger impact on natural mapping and need satisfaction in gaming: the use of VR motion controllers or the tracking of the head movements using a VR 360-degree HMD.

Based on SDT, the current analysis concentrated on natural mapping and need satisfaction as underlying factors of VR game enjoyment. However, in general, it would be possible to extend our model beyond the core mechanisms of SDT in future research and to discuss and examine how additional variables (such as presence, immersion, flow, or others) could be integrated.

Similar to many previous studies on game use and need satisfaction (e.g. Przybylski, Ryan, & Rigby, 2009; Reinecke et al., 2012; Rieger et al., 2014; Tamborini et al., 2011), the current study focused on a single-player situation and the satisfaction of autonomy and competence needs. However, there is first evidence that social features are important factors for the adoption and perceived enjoyment of VR devices (Lee et al., 2019). Existing studies on non-VR games have shown that social interactions with fellow players and the satisfaction of relatedness needs contribute to game enjoyment (e.g. Reer & Krämer, 2020a; Ryan et al., 2006; Tamborini et al., 2010). Another interesting task for future studies therefore may lie in investigating relatedness need satisfaction in the context of VR multiplayer games. In view of the COVID-19 pandemic and the resulting restrictions on social life, this topic is currently of particular relevance.

We used the role-playing game Skyrim as the stimulus material. One reason was that the game features a VR version and an identical non-VR version, affording strong experimental controls to compare the gaming experience in both versions. We believe that this choice was justified as the VR version of Skyrim is popular and the game offers a good impression of current VR game content. However, we of course cannot guarantee that our results are generalizable to all types of VR games. Therefore, our findings should be replicated with other types of games.

4.2. Conclusion

In taking the SDT approach towards VR gaming experiences, our study expands previous works that focused on concepts like presence or immersion. Against the background of our results, future studies should consider natural mapping and need satisfaction as additional factors in explaining the attractiveness and enjoyment of VR games.

Our findings are also of relevance for the games industry and for research on the acceptance and adoption of VR technology. Further, our study may serve as a starting point for the examination of other possible effects of VR games. These range from negative aspects, like the disordered and maladaptive use of digital games, to positive psychological outcomes, like stress reduction and recreation.

Author statement

Felix Reer: Conceptualization, Methodology, Writing – original draft, Formal analysis, Investigation, Writing – review & editing, Project administration. **Lars-Ole Wehden**: Conceptualization, Investigation, Writing – review & editing. **Robin Janzik**: Conceptualization, Investigation, Writing – review & editing. **Wai Yen Tang**: Conceptualization, Investigation, Writing – review & editing. **Thorsten Quandt**: Supervision, Writing – review & editing.

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