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Completed Research Paper

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Abstract

Collaborative virtual reality (VR) is increasingly receiving attention, but the effects of context-specific variables and the interplay of telepresence, interactivity, and immersion as VR's distinctive characteristics in such settings are little understood. Besides these three VR characteristics, we investigate in a quantitative study with 102 participants the influence of social presence, i.e. the sense of community; media naturalness, or the similarity of communication to face-to-face-interaction; and trust between users. Based on partial least squares structural equation modeling, we confirm the importance of interactivity and immersion, but not of telepresence. Moreover, we find that trust is essential for collaborative VR experiences, but social presence and media naturalness seem negligible. Finally, we show that immersion is a main driver of users' intention to collaborate. Besides providing practitioners with insights for creating VR experiences, our study highlights that findings from research on individual VR use are not readily transferable to collaborative contexts.

Keywords: Collaboration, virtual reality, social presence, media naturalness, trust

Introduction

The development of virtual reality (VR) technology and content has attracted large investments, especially from the gaming industry and social networks. In both fields, collaboration as a process "in which two or more agents (individuals or organizations) share resources and skills to solve problems so that they can jointly achieve one or more goals" (Boughzala and de Vreede 2015, p. 133) is proving to be a promising application area. Practical examples include collaborative multiplayer games, such as "Star Trek: Bridge Crew," or software that provides a shared VR environment for individuals or distributed teams of a company, such as Facebook Spaces or Rumii.

Communicating with other users and interacting with their avatars, i.e. virtual representations of users, might be important for a user's perception of collaborative VR experiences. But while creation and technology issues that accompany collaborative VR were first investigated several decades ago (Churchill and Snowdon 1998) and repeatedly since then (e.g., Moore et al. 2005; Pouliquen-Lardy et al. 2016), factors driving user intention to collaborate in VR have been explored to a lesser degree. Insights from other fields are transferable only to a limited extent, as VR possesses specific characteristics that need to be considered, mainly interactivity, telepresence, and immersion (e.g., Ryan 2015; Steuer 1992; Walsh 2002).

We address this problem by investigating the interplay and effects of these characteristics in a collaborative environment. In addition, we consider the influence of other users by examining users' awareness of community resulting from other users' presence (Tu and McIsaac 2002), the naturalness of users' communication with other users (Kock 2004), and the trust between users of the same team (Gefen et al. 2003), as all of these presumably play an important role in VR. In doing so, we seek to answer the following research question:

How do VR and collaboration characteristics drive a user's intention to collaborate?

Our results stem from a study of 102 users of "Star Trek: Bridge Crew." As teams, they played several collaborative missions of the game and completed a questionnaire on how they perceived VR as well as the presence of and communication with team members. A quantitative analysis of results applying partial least squares structural equation modeling revealed that telepresence as one of VR's distinctive characteristics has no significant effect on immersion, which is contrary to the strong and significant results found in studies on individual VR consumption (Mütterlein 2018). In addition, we find that trust among team members is a major driver of immersion in collaborative VR, whereas the presence of other users and the naturalness of communication with them are not. Finally, our results show that immersion plays a decisive role in users' intentions to collaborate in VR.

Overall, our findings confirm the importance of interactivity and immersion as VR's distinctive characteristics, but the role of telepresence seems negligible in collaborative settings. The latter is also true for the awareness of the presence of other users and the naturalness of communication with them, indicating that, e.g., the design of avatars and the capabilities to communicate do not have to be connected to reality. In contrast, trust among team members needs to be facilitated, which highlights the importance of the rich body of literature on trust for further research on collaborative VR.

The remainder of this paper is structured as follows: in our theory section, we explain the distinctive characteristics of VR as well as social presence, media naturalness, and trust as the main theoretical foundations of our study before we derive hypotheses and present our research model. We continue by describing our method and results, followed by a discussion on the implications for theory and practice. We close our paper with a short conclusion, limitations of the study, and suggestions for further research.

Theoretical Background

Interactivity, Telepresence, and Immersion as Characteristics of Virtual Reality

VR has its technological origins in the 1960s when Sutherland introduced glasses that could enhance a real environment with virtual objects, i.e., an augmented reality device (Sutherland 1965). In the following decades, this foundation was used to create glasses that completely excluded real environments. Such head-mounted displays are today's standard VR devices (Anthes et al. 2016) in that they are an important component of "the sum of the hardware and software systems that seek to perfect an all-inclusive, immersive, sensory illusion of being present in another environment" (Biocca and Delaney 1995, p. 63). From a user's point of view, interactivity, telepresence, and immersion are the distinctive characteristics of VR (e.g., Ryan 2015; Steuer 1992; Walsh 2002). Interactivity describes "the degree to which users of a medium can influence the form or content of the mediated environment" (Steuer 1992, p. 80). Telepresence means that a medium is used to create a subjective feeling that one is in another environment. Immersion is the subjective experience of feeling totally involved in and absorbed by the activities conducted in this environment.

The measurement of the three characteristics has been discussed extensively in VR research, with a focus especially on the objective versus subjective measurement of immersion. According to some researchers, immersion can be measured objectively as a specific of the technology, i.e., the degree of immersion a user experiences depends on the quantity and quality of sensors in the VR device or the quantity and quality of sensors that are used by the VR content (Slater 1999). Other researchers question this view and highlight that immersion has to be measured as a psychological state of mind, i.e. subjectively as perceived by the users (Witmer and Singer 1998). We take the latter point of view because this better allows for capturing individual differences in the perception of the same VR content, which is important in investigating the use of collaborative VR applications.

In practice, such applications are often labeled "social VR." This refers to people meeting in virtual environments to spend time together or work on collaborative tasks, whether playing a multiuser game, developing prototypes or products together, or meeting in VR conference rooms. While virtual collaborations are investigated frequently (e.g., Brown et al. 2004; Nah et al. 2017), VR is much less in the focus of collaboration research. Previous works cover topics such as how collaborative VR can support work (Churchill and Snowdon 1998), helps in autism therapy (Moore et al. 2005), or affects mental workload (Pouliquen-Lardy et al. 2016), but the role of VR's distinctive characteristics needs to be considered more systematically. Their effects in individual VR environments have attracted sustained attention in the past decades (e.g., Kampling 2018; Steuer 1992), but we know little about how other users in a virtual environment affect these characteristics.

Although earlier research has focused on telepresence as VR's decisive characteristic (e.g., Steuer 1992), recently attention has been paid to the role of immersion (Kampling 2018). While telepresence describes the subjective experience of being in another place in VR, immersion summarizes the activities executed in this VR. Thus, for us, telepresence relates to places and is a prerequisite to experience immersion, which relates to the activities conducted in those places. Furthermore, the concept of immersion is often linked to other concepts, especially flow (Cahalane et al. 2012), but immersion and flow need to be distinguished. Although there are connections between the two, and immersion is often treated as a part of a flow experience, flow entails many other aspects such as having a feeling of control over the experience (Csikszentmihályi 1990). For the purpose of our study, the features that are a part of immersion allow for a clearer focus on the emotional aspects that are relevant to answer our research question. For this reason we focus on immersion instead of other related concepts. As we aim at examining how VR and collaboration characteristics influence users' intentions to collaborate, we also assume that immersion plays a primary role and is the main driver of users' intentions to collaborate. Immersion is influenced by interactivity and telepresence as variables that relate to the individuals playing and their perception of the VR experience (Mütterlein 2018). These factors are independent of other users being present in a virtual environment. Thus, we label them as the *individual domain*.

In addition to these individual-related variables, we need to consider variables that are distinctive for collaborative contexts in VR, i.e., variables that depend on other users being present in the same VR experience. While many variables are potentially relevant for collaboration, we focus on two variables that relate to the unique collaborative technological capabilities of VR: First that the technology is able to create a virtual environment in which the avatars of other users are viewed from the first-person perspective in life size. This can lead to users feeling the presence of other users almost physically, creating a tight sense of community among users of a collaborative VR experience. We use social presence theory as the theoretical foundation to study this phenomenon. Second that the technology is able to let users interact in various ways with each other, as they cannot only hear each other but also see the faces of their avatars and their body movement. This can lead to users perceiving communication with other users as almost natural, reducing their awareness of the technology and having them focus more on the experience. The theoretical foundation for studying this phenomenon is media naturalness. Besides these two variables that stem from technological aspects of VR, we consider trust as an important non-technological variable for collaboration in VR, because it might also enable users to focus on the experience instead of worrying about the behavior of other users. With trust being a significant factor in various fields of digital media, it is highly likely that trust also has a significant effect in VR. In addition, the influence of trust in collaborative VR has not been part of in-depth research so far. We summarize the three variables, social presence, media naturalness, and trust, as the *collaboration domain*.

Social Presence

Social presence was originally defined as "the degree of awareness of another person in an interaction and the consequent appreciation of an interpersonal relationship" (Tu and McIsaac 2002, p. 133). But with the rise of computer-mediated communication, the definition of social presence has changed. Considering these new technologies and focusing on an online learning environment, Tu and McIsaac define social presence as "a measure of the feeling of community that a learner experiences in an online environment" (2002, p. 131). For VR, this means that such a feeling of community occurs when all

members of a collaborative event feel that they co-habit the same virtual environment and experience the same things. Social presence theory has been used in multiple studies across various types of media, including social media platforms (Cheung et al. 2010), online learning communities (Kear 2010), virtual worlds as well as text chats (Traphagan et al. 2010), but insights are not readily transferrable to VR because the distinctive characteristics of VR have not been covered systematically.

Social presence depends on two concepts, intimacy and immediacy (Tu and McIsaac 2002). Intimacy is conveyed through body language, such as eye contact, body leaning forward, proximity, and smiling (Burgoon et al. 1984). Reducing physical distance and discussing personal topics of conversation also enhance intimacy (Argyle and Dean 1965). Immediacy is described as the psychological proximity of an individual to his/her communication partner (Cobb 2009). Physical proximity, formality of dress, and facial expressions affect immediacy. In addition to this, privacy has been suggested as also relevant to social presence, although the effect has been found to be insignificant (Tu and McIsaac 2002). This can be explained by the fact that while sharing private information is seen as risky and as possibly affecting the feeling of community, it does not normally have any immediate consequences and therefore does not decrease the perception of social presence. Thus, we will not consider this aspect further.

Media Naturalness

Media naturalness theory was developed by Kock (2004) at a time when internet-based and computer-mediated communication was already an integral part of everyday life. Media naturalness is defined as "the similarity between a […] medium and face-to-face interaction" (Kock 2004, p. 333), because face-to-face communication is seen as the most natural form of communication and, thus, preferred by users. Kock (2005) roots this assumption in Darwin's evolution theory, arguing that throughout most of human history, face-to-face communication has been the primary means of communication between people. Other forms of communication, e.g., writing, are relatively new, therefore humans have not fully adjusted cerebrally to such forms of interaction. As a consequence, every type of communication that differs from face-to-face communication requires an added effort on the part of the human brain. In its difference from face-to-face communication, according to Kock (2004), a medium can even be more natural than face-to-face communication, leading to an information overload. As an example, super-rich VR is a medium with significantly more communicative stimuli than face-to-face interaction, which can overwhelm the user. Therefore, any deviation from face-to-face communication decreases media naturalness.

To approximate face-to-face communication, communication through media has to fulfill at least five elements of communication: 1) colocation, which enables the users to see and hear each other, 2) synchronicity, which enables users to quickly communicate with each other, 3) the ability to convey facial expressions, 4) the ability to convey body language, and 5) the ability to convey speech. Kock (2005) states that adding one of those elements to a communication medium (e.g., adding video chat to a text-based chat) increases the naturalness of that medium. Also, a medium that fulfills one of these elements to a higher degree than another one (e.g., high quality video chat in contrast to standard quality video chat) will also result in a higher degree of naturalness, as long as the medium does not become super-rich. Media naturalness theory has been examined in a variety of fields, ranging from education (Paretti et al. 2007) to the development of virtual environments and e-negotiations (Citera et al. 2005). As VR often focuses on creating virtual environments in which communication with others feels as natural as possible, we expect media naturalness to also be a major factor in collaborative VR experiences.

Trust

Another important aspect necessary for collaboration is trust. Over the years, studies have examined trust in a variety of fields, e.g., trust between business partners, buyer-seller trust, and interpersonal trust (Gefen et al. 2003). In any functioning team, interpersonal trust is necessary to achieve a task or complete a mission. Among a variety of conceptualizations, it has been defined as the "willingness to be vulnerable to another party based on the belief that the latter party is 1) competent, 2) open, 3) concerned, and 4) reliable" (Mishra 1996, p. 5). When it comes to digital media, trust in e-commerce

and online-shopping has been identified as "a primary benefit which is nearly as important as the technical attributes of a Web site such as usefulness" (Gefen et al. 2003, p. 77).

When applied to a VR context, a user is willing to be vulnerable in the sense of giving another user responsibility over issues inside the experience. Users must have confidence to transfer tasks to other users and believe that these other users will fulfill these tasks to the best of their ability. Users who do not take an experience seriously and therefore do not perform in the best way possible are believed to be a major negative influence on how much another user is enjoying a virtual experience. The importance of trust for collaborations in VR is also highlighted by the extensive discussion around cyberbullying (Wilson 2016).

Research Model and Hypotheses

Our research model consists mainly of the two domains, the individual domain and the collaboration domain (see Figure 1). H1–H3 belong to the *individual domain*, which relates to factors that stem from individual VR usage. This part encompasses the interplay of interactivity and telepresence as important characteristics of VR and their effects on immersion. H4–H6 belong to the *collaboration domain*, i.e., effects of factors that are specific to collaborative VR contexts. Immersion as VR's decisive characteristic is at the center of the model. Its effect on users' intention to collaborate is included as H7 on the right. The hypotheses are explained below.

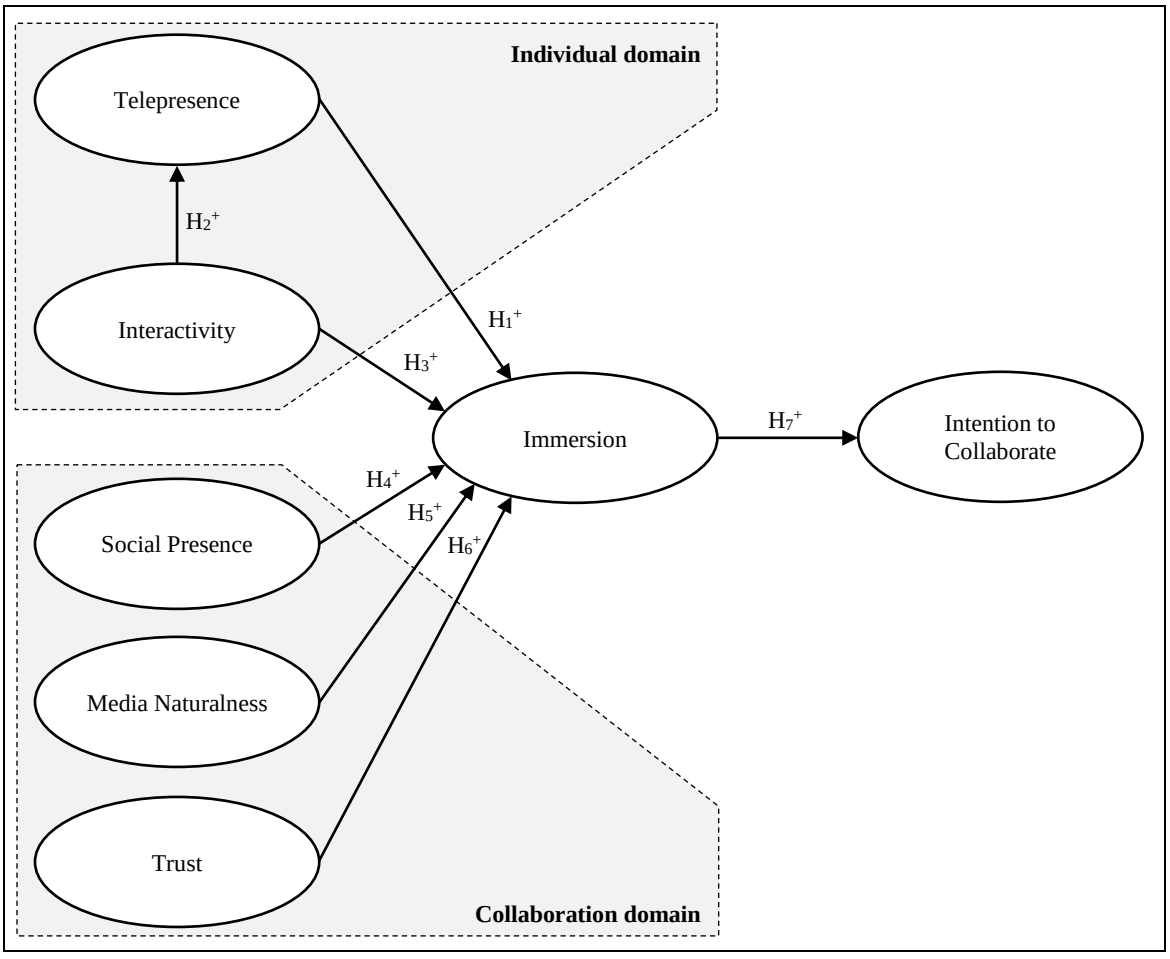

Figure 1. Research Model

Individual Domain

In individual use contexts, the relation of VR's distinctive characteristics has been investigated frequently. Early findings indicate that immersion influences telepresence, but this is based on measuring immersion on an objective technological level and telepresence as an outcome on a subjective psychological level (Slater 1999). When both are measured as subjectively perceived by

users, the relation becomes less clear and depends on the definitions applied (McMahan 2003) as well as the measurement model used (Witmer et al. 2005). We apply definitions that restrict telepresence to feelings of being present in another environment and immersion to feeling involved and absorbed by the activities conducted there. Recent research suggests that this differentiation leads to telepresence being an important driver of immersion (Kampling 2018). We follow this view and hypothesize:

H1: Telepresence has a direct and positive influence on immersion in collaborative VR.

When it comes to interactivity, researchers agree that being able to influence an environment is an important driver of feeling present in this environment (Steuer 1992) as well as of feeling absorbed by and involved in the activities conducted there (Hsu 2010). Interactivity has also yielded various positive effects in VR (e.g., Bailenson et al. 2008). Following these findings, we assume that interactivity influences telepresence and immersion in collaborative VR settings positively:

H2: Interactivity has a direct and positive influence on telepresence in collaborative VR.

H3: Interactivity has a direct and positive influence on immersion in collaborative VR.

Collaboration Domain

Several studies emphasize the importance of social presence to improve performance in a medium. Gunawardena (1995) names social presence as a major factor in improving the effectiveness of traditional and technology-based learning environments. Tu and McIsaac (2002) also describe social presence as a crucial element of online interaction. Users are assumed to feel more comfortable interacting online when the sense of being in a community is enhanced. Especially in VR, where users are able to see each other, creating a real-life atmosphere and giving users the feeling of not just "playing a game" is expected to increase immersion. Leong (2011) also emphasizes the positive impact of social presence on cognitive absorption in online learning environments. Based on these insights, we also assume that social presence plays an important role in users' perceptions of collaborative VR experiences because sharing the same things in a virtual environment should enable users to become more involved in and absorbed by the virtual environment.

H4: Social presence has a direct and positive influence on immersion in collaborative VR.

Empirical findings on the effects of media naturalness are mixed (e.g., Kock et al. 2007). However, based on theoretical considerations, we argue that it positively influences immersion in collaborative VR. From an evolutionary perspective, this is so because the human brain is most likely designed to process information conveyed via face-to-face communication effortlessly, e.g., by having brain circuits capable of recognizing faces and creating facial expressions (Kock 2005). When any of these communication components are missing, the human brain is forced to compensate. Although the brain is able to learn, compensating for the missing components requires evolution of the brain over many centuries. Since this is presumably not possible in the lifespan of a human being, engaging in any kind of medium in which any of the communication attributes are missing leads to higher cognitive effort (Kock 2005). With a higher cognitive effort, the user is presumably not able to fully concentrate on and be immersed in the VR experience. Therefore we hypothesize that a higher level of media naturalness will lead to a higher level of immersion.

H5: Media naturalness has a direct and positive influence on immersion in collaborative VR.

Immersion is described as the state of total engagement of a user. Attention is directed to a specific task, and other activities are neglected (Agarwal and Karahanna 2000). In order to reach this level of immersion, users must be sure that their virtual environment is free from distraction. Only then can they fully concentrate on the game and immerse themselves in it. Trust between users supports this process. If users are absolutely sure that other users take the VR experience seriously, they can focus on the experience and dive more deeply into the virtual world instead of worrying what other users will do. Based on such theoretical considerations on trust (e.g., Hsu et al. 2011; Ridings et al. 2002), we hypothesize that a higher level of trust has a positive influence on the level of immersion.

H6: Trust has a direct and positive influence on immersion in collaborative VR.

Intention to Collaborate

Immersion, sometimes also referred to as absorption, is the key feature which differentiates VR from other types of media. Flow and cognitive absorption (Agarwal and Karahanna 2000) are well researched and cover aspects of immersion as well. Findings on these demonstrate an influence on the behavioral intention to use a technology (Agarwal and Karahanna 2000). Chandra et al. (2009) also examined the influence of absorption, showing a strong positive influence of absorption on the behavioral intention to use virtual worlds for collaboration. We hypothesize that a high level of immersion will also lead to a higher behavioral intention to collaborate.

H7: Immersion has a direct and positive influence on the intention to collaborate.

Method

In cooperation with a VR center in Munich, Germany, we used its facilities to conduct a four-week study. The VR center offers paying customers the opportunity to use state-of-the-art VR technology and consume the latest VR experiences. Via promotion at the center and through a university mailing list, we invited interested participants to register for our study. We then assigned groups of up to four people a two-hour spot when they came to the center, consumed a collaborative VR experience together, and filled out a questionnaire.

As the VR experience we chose "Star Trek: Bridge Crew," developed by Ubisoft for HTC Vive. Users are able to be become a character of the crew from the original Star Trek franchise. Each character is responsible for different parts of the spaceship "Enterprise" (as captain, tactical officer, engineer, and helm officer). All characters have to work together to accomplish the assigned task. The game begins after users have played a tutorial in their respective roles. In the first task of the game, the Enterprise has to be navigated to a new location. From there, tasks become increasingly more difficult, and by the end, multiple opponents are trying to destroy the Enterprise, requiring the collaborative skills of all participants under time constraints to defeat the opponents.

Our study was divided into four parts. First, participants answered a questionnaire covering control questions, e.g., about demographics, personality traits, and previous VR experience. Second, participants took the tutorial in order to familiarize themselves with the VR experience and their individual roles. Third, the entire group began its first collaborative mission. The groups completed multiple tasks such as scanning other spaceships, flying to other galaxies, or evacuating passengers, where each team member contributed as their character, and a joint team effort was necessary for the tasks to be successful. To ensure comparability between the groups, each team completed the same mission. Usually, the groups spent between 45 and 60 minutes in the VR experience. Fourth, participants answered another questionnaire that covered the constructs of our model. All participants were asked to not interact with their team members after the VR experience to restrain from influencing their answers.

The scales for telepresence (based on items from Animesh et al. 2011; Nah et al. 2011; Nelson et al. 2006), interactivity (based on items and definitions from Animesh et al. 2011; Johnson et al. 2006; Steuer 1992), immersion (measured as a second-order formative construct consisting of involvement and absorption; based on items from Engeser and Rheinberg 2008), social presence (self-developed), media naturalness (self-developed), trust (based on items from Jarvenpaa et al. 1998), and intention to collaborate (based on items from Park et al. 2012) could be answered on a standard seven-point Likert scale. This scale ranged from "strongly disagree" to "strongly agree." In addition, we provided an "I don't know" option for respondents who could not decide on an answer on the Likert scale. Furthermore, we included political interest as a marker variable in the questionnaire, which was not be related to other constructs of the model (Lindell and Whitney 2001; Williams et al. 2010). Media naturalness belongs to the collaboration domain in this paper, while it could also be linked to the individual domain. As an example, the naturalness of the avatar a user selects could also be analyzed through the lens of media naturalness. However, this is not the focus of our paper so we only included items measuring media naturalness related to other users.

Results

After eliminating questionnaires that were answered systematically (e.g., straight lining) or that had too many missing values, we were left with 102 questionnaires that could be used for evaluating our research model. In our exploratory factor analysis with IBM SPSS 23, all scales could be identified with three or more items. We considered only items with factor loadings > 0.7 for further analyses (Matsunaga 2010). The only exception was the TP3 ("I forgot about my immediate surroundings when I was using the VR content") as an item to measure telepresence. Despite not fulfilling the threshold of 0.7, we did not exclude this item because it had been used in a previous study (Mütterlein 2018). By including TP3, we were able to exactly compare our results to findings from individual VR consumption. In addition, this item fulfilled less strict guidelines for factor loading measurements (Chin 1998), and including it did not compromise the Cronbach's Alpha value of the construct or alter the effects of our model significantly. All results of our factor analysis can be found in Table 1.

Table 1. Constructs and Results of Factor Analyses

Construct		**Mean**	**Std. Dev.**	**Factor Loading**	**Cronbach's Alpha**
Immersion—Absorption					0.860
AB1	I didn't notice time passing.	5.92	1.514	0.902	
AB2	I was totally absorbed in what I was doing.	6.01	1.284	0.901	
AB3	I was completely lost in thought.	4.69	1.705	0.855	
Immersion—Involvement					0.790
IN1	I had no difficulty concentrating.	5.71	1.453	0.874	
IN2	My mind was completely clear.	5.53	1.501	0.820	
IN3	The right thoughts and movements occurred of their own accord.	5.05	1.576	0.825	
Intention to Collaborate					0.904
IC1	I intend to use collaborative VR content in the future.	5.23	1.591	0.918	
IC2	I am going to utilize collaborating while playing VR games.	5.59	1.470	0.918	
IC3	I predict I would use collaborative VR content in the future.	5.16	1.511	0.854	
Interactivity					0.769
IT1	The VR content allowed me to interact with the virtual world.	5.91	1.063	0.787	
IT2	I had the feeling that I could influence the virtual world of the VR content.	5.21	1.544	0.836	
IT3	The VR content was interactive.	5.93	1.196	0.871	
Media Naturalness					0.851
MN1	Playing together with my teammates felt very natural.	5.24	1.587	0.818	
MN2	Interactions with my teammates felt very similar to face-to-face communication.	3.88	1.836	0.893	

MN3	It felt like I was meeting my teammates in real life.	3.48	1.690	0.894	
Social Presence					0.762
SP1	It felt like we all had similar experiences while playing the VR content.	5.44	1.451	0.864	
SP2	It felt like we shared the same place while playing.	6.07	1.265	0.770	
SP3	I experienced the same things as my teammates.	5.23	1.752	0.836	
Telepresence					0.750
TP1	The VR content created a new world for me, and this new world suddenly disappeared when the VR content ended.	5.10	1.583	0.851	
TP2	When the VR content ended, I felt as if I returned to the "real world" after a journey.	4.96	1.659	0.817	
TP3	I forgot about my immediate surroundings when I was using the VR content.	4.65	1.767	0.636	
TP4	The VR content seemed to be "somewhere I visited" rather than "something I saw."	4.87	1.606	0.710	
Trust					0.904
TR1	I could rely on those with whom I work in this team.	5.23	1.591	0.918	
TR2	Overall, the people in my team were very trustworthy.	5.59	1.470	0.918	
TR3	We had confidence in one another in this team.	5.16	1.511	0.854	

After confirming that our constructs' convergent and discriminant validities were within the thresholds suggested by literature (Fornell and Larcker 1981; Henseler et al. 2015), we used partial least squares structural equation modeling (PLS-SEM) with SmartPLS 3 (Ringle et al. 2015) to evaluate the relationships within the model and applied bootstrapping for significance testing (Goodhue et al. 2007). We chose PLS-SEM because it is as suitable for our sample size as a covariance-based approach (Goodhue et al. 2012) but more suitable to explore new theoretical relationships as is the case in our study (Hair et al. 2017). The marker variable had no significant correlations with other variables, indicating that common method bias is not an issue in our study (Lindell and Whitney 2001; Williams et al. 2010). All path coefficients together with the levels of significance can be found in Figure 2. Levels of significance are indicated with the respective p values, with * for $p < 0.05$, ** for $p < 0.01$ and *** for $p < 0.001$.

Our results show that interactivity has a strong positive and significant effect on immersion, but telepresence has no effect. In addition, interactivity influences telepresence. Thus, regarding the *individual domain*, hypotheses H1 and H3 are confirmed, but H2 is not. In the *collaboration domain*, we found a strong positive and significant effect of trust on immersion, but no significant effects of social presence and media naturalness on immersion. This means that hypotheses H4 and H5 are not supported but H6 is. Finally, we found a strong positive and significant effect of immersion on the behavioral intention to collaborate. This confirms hypothesis H7.

As belonging to a team could affect results, we added a dummy variable for group affiliation. This did not change our findings significantly. Another approach to control for such effects would have been to analyze our data with multilevel modeling, but such an analysis can lead to biased results when the number of groups is relatively small (< 50), as it was in our study (Hox & Maas 2002).

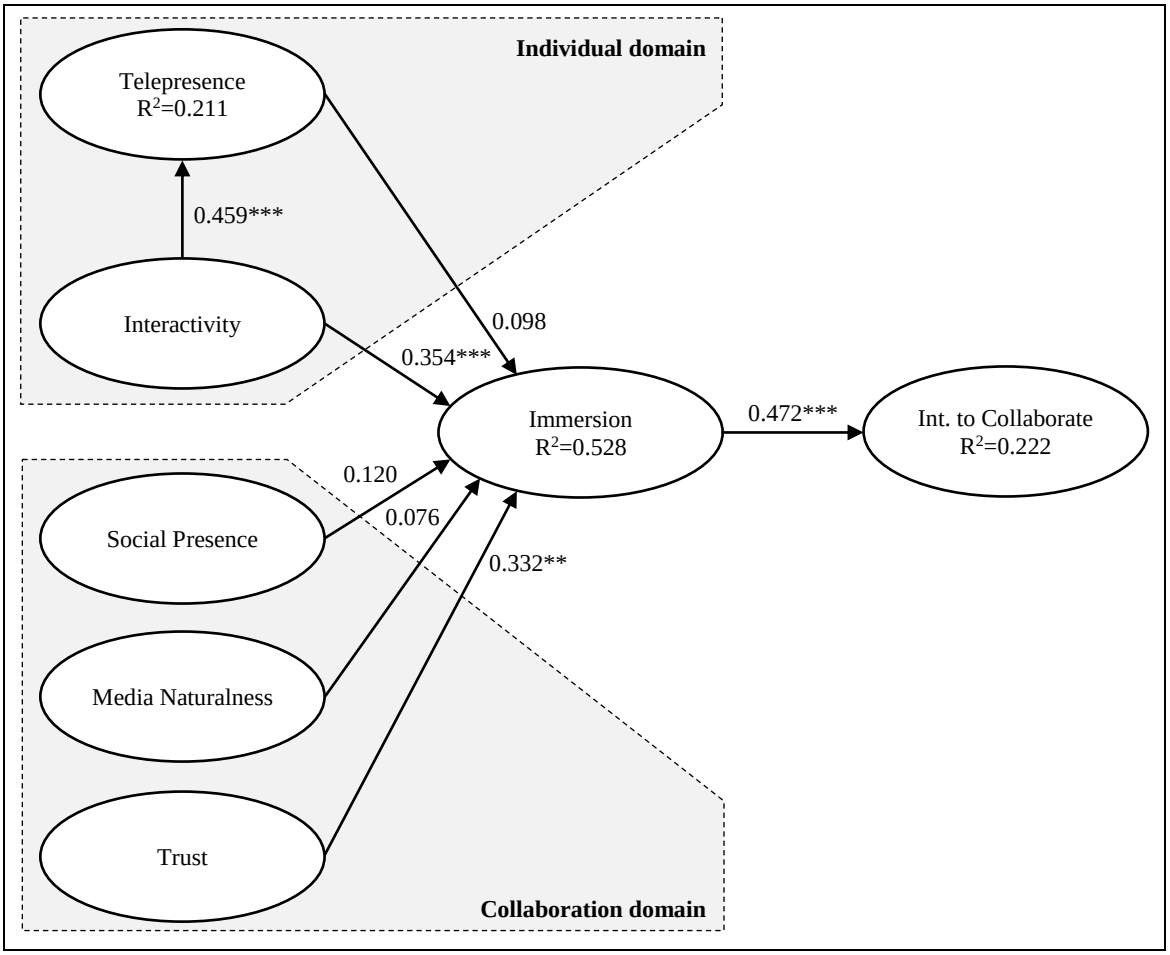

Figure 2. SEM Results

Discussion, Implications, and Limitations

Our findings offer rich insights into the interplay of telepresence, interactivity, and immersion as VR's distinctive characteristics in collaborative settings (variables from the *individual domain*); the influence of social presence, media naturalness, and trust as concepts that were assumed to be relevant in collaborations (variables from the *collaboration domain*); and the effect of immersion as the key characteristic of VR on user's intention to collaborate in VR.

Regarding the interplay of VR's distinctive characteristics, our results confirm that interactivity is important for telepresence as well as for immersion. Users need to be able to influence the form and content of the virtual environment to create the feeling that they are in the other environment and to feel involved in and absorbed by the activities conducted there. While this highlights the importance of interactivity (Bailenson et al. 2008), it is surprising that we did not find an effect of telepresence on immersion, as is the case in individual VR consumption (Kampling 2018). This could be due to users being aware that they communicate with real persons in the real world, which might lessen the effect of feeling in another environment. For theory, this implies that research insights are not readily transferable from studies on individual VR consumption to collaborative settings. Apparently, other factors play an important role in such settings, but these need to be investigated in greater depth than has previously been done. For practice, this means that what works in individual VR experiences is not necessarily beneficial in collaborative VR experiences. Perceiving a virtual environment as "real," as captured via telepresence, is less relevant than, e.g., the way users can interact with this environment.

In addition to interactivity, our findings show that trust is more important than telepresence. This means that believing that team members are reliable and overall trustworthy helps users to relax in a virtual environment and fully focus on the activities conducted there. However, we did not find effects of social presence or media naturalness. While it is still plausible that users prefer feeling a sense of

community and communication that is as close to face-to-face interaction as possible, our findings show that this does not contribute to players becoming immersed in VR. This could be explained by social presence and media naturalness consisting of multiple dimensions. As an example, it is possible that colocation and synchronicity, two components of media naturalness, enhance immersion, while the other components of media naturalness have no significant influence (Kock 2005). Regarded as one factor, media naturalness could then have no significant effect on immersion. For theory, our findings highlight that trust is more important than many technological attributes of an application (Gefen et al. 2003), but this should be verified in future studies taking the dimensions of social presence and media naturalness into account. For practice, this means that collaborative VR experiences need to have trust-building elements, e.g., introducing users to each other. It is also essential that there is no interference while players are experiencing the virtual world because this reduces trust between team members, such as unexpected or uncontrolled behavior of the avatars of team members. In addition, issues such as cyberbullying need to be prevented with technological countermeasures, e.g., desaturating the VR experience for users who misbehave (Wilson 2016).

Finally, our study demonstrates that immersion is an important driver of users' intention to collaborate in VR. Feeling involved in and absorbed by the activities conducted in VR is one of the main aspects that ensure the ongoing use of collaborative VR experiences, which underlines previous findings about individual VR consumption (Mütterlein 2018). For theory, this shows that conceptualizing telepresence and immersion as subjective perceptions and differentiating them through a focus on either the virtual environment or the activities conducted there is a suitable approach to investigate their influence in different VR contexts. For practice, this highlights that a focus on the variables that drive immersion ultimately leads to a higher intention to collaborate. In that sense, VR developers are well advised to focus especially on interactivity and trust when creating collaborative VR experiences.

Besides the issues outlined above, avenues for future research stem from the limitations of our work. One of the main aspects requiring further examination is generalizability. In order to gather comparable data, every participant played the same mission within the same VR experience. It remains unclear whether the results can be expanded to other collaborative contexts. As an example, media naturalness could have a more significant impact on immersion in a VR experience that is capable of conveying a higher range of facial expressions and body language than "Star Trek: Bridge Crew." In addition, there is a wide range of factors that were not covered in our model but that could influence the experience, e.g., a skilled team leader might have helped the rest of the crew understand the mission and tasks better or the competence of team members or the overall constellation of teams could have an impact. Letting users change roles or switching teams while experiencing different missions could improve generalizability of results. Furthermore, some groups had team members that knew each other beforehand. Such teams could have collaborated in other ways than teams in which members were not familiar with each other, which might have led to a different experience. Future research with the help of qualitative studies should focus on understanding those effects.

Conclusion

Our research was motivated by an interest in the effects of VR and collaboration characteristics on users' intention to collaborate. To examine these effects, we highlighted the importance of immersion for VR experiences. We identified potential drivers of immersion in the *individual domain*, i.e., telepresence and interactivity, and in the *collaboration domain*, i.e., social presence as a measure of a user's awareness of other users' presence, media naturalness as the similarity to natural communication among users, and trust between users of the same team. We then gathered data to quantify the influence of these variables. An analysis applying PLS-SEM showed that similar to individual VR use contexts, interactivity is highly relevant for immersion, but telepresence is not. Furthermore, we found that social presence and media naturalness as variables relating to the specific technological capabilities of VR are of little importance for immersion, but trust is a key driver of immersion, and, through the mediating effect of immersion, essential for the intention to collaborate.

These findings provide researchers and practitioners with rich insights on how collaborative VR needs to be examined differently from individual VR and which factors are crucial in creating collaborative VR experiences. All in all, our results show that collaboration in VR depends only to a small extent on

technological issues, such as optimal representation of team members through avatars. Instead, research and practice should focus on the collaboration itself, i.e., how users interact with each other and their virtual environment. These are important drivers of immersion in collaborative VR and ultimately lead to a greater intention to collaborate.

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