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Being There: Spatial Presence in Immersive Environments

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Completed Research

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Abstract

Immersive technologies are becoming ubiquitous in every corner of modern society. From learning environments in the classroom to behavioral genomics research and beyond, the elusive goal of making the virtual seem real and come to life is moving at a rapid pace. Spatial presence is one of the most critical aspects of user experience in immersive technologies that is associated with the intended outcome of the immersive technology use. Even though spatial presence is recognized as an important aspect of user experience in immersive technologies, there is no holistic account of factors affecting spatial presence. This study conducts a comprehensive literature review to identify individual, technological, and contextual factors associated with spatial presence in immersive technologies. In addition, we provide a research agenda that illustrates current gaps in both the extant literature and our understanding of spatial presence in immersive environments.

Keywords

Immersive technology, virtual reality, user experience, spatial presence, literature review

Introduction

The world of simulated 3D environments and virtual reality has long existed in science fiction movies and books. Today, immersive technologies (*technologies that enable users to experience a sense of immersion in a simulated experience by blurring the boundary between the physical and virtual* (Suh and Prophet, 2018)) have become a reality. Their application range is as wide as the imagination can dream. From learning environments in the classroom (Dede, 2009), to complex commercial applications (Ortega et al., 2019), to social and behavioral genomics research and beyond (Persky and McBride, 2009), the elusive goal of making the virtual seem real and come to life is moving at a rapid pace (Riva et al., 2004).

The IS community recognizes the importance of studying immersive environments. Indeed, Yoo (2010) suggested expanding the boundaries of IS research by taking in on the emergent field of experiential computing. In experiential computing, individual perceptions of space, defined as "structure that enables things to be connected as humans experience them," can be an essential aspect of user experience. Humans actively construct their perceptions of space through the meaning they ascribe to the objects and their interactions with such things in the environment (Milligan, 1998; Yoo, 2010). A virtual space theory developed by Saunders et al. (2011) also emphasizes the importance of sensory experiences and interactions within "space". In immersive environments, individual perceptions of space translate into spatial presence, or a sense of "being there" (Biocca, 2001).

Indeed, helping users achieve a sense of spatial presence is currently one of the primary goals for designing virtual worlds (Chaturvedi et al., 2011). Particularly, spatial presence can enhance flow (e.g., Animesh et al.,

2011), thereby leading to positive outcomes of the immersive technology use (e.g., enhancing user enjoyment, knowledge, among others) (Nah et al., 2011, Suh and Chang, 2006). Situations that require the user's attention to the physical world might not be desirable for inducing spatial presence, given individual's limited cognitive capacity (Bailey et al., 2012).

There exist various theories on spatial presence. For example, the attentional model of spatial presence states that user's attentional resources directed towards mediated stimuli in the virtual environment can evoke spatial presence (Draper et al., 1998). However, it is still unclear what contextual information users need to perceive to experience spatial presence. Furthermore, Steuer (1992) described a theory in which spatial presence is determined by vividness (i.e., visual, auditory, and other characteristics of the content displayed) and interactivity (i.e., capabilities of the immersive system). Some spatial presence theorists recognize that, in addition to system capabilities, we also need to consider individual characteristics of users (e.g., mental models of users, their abilities, among others) (Schubert et al., 1999; Sanchez-Vives and Slater, 2005; Wirth et al., 2007). Overall, the existing theories seem to converge in a sense that they recognize that technological (i.e., technical features), individual (i.e., states, traits, or abilities), and contextual (i.e., characteristics of the content displayed) factors can contribute to user's experience of spatial presence (Hartmann et al., 2015). Yet, no study holistically accounts for specific technological, individual, and contextual factors associated with spatial presence.

This study, therefore, aims to holistically identify factors associated with user experiences of spatial presence in immersive environments. Specifically, we focus on immersive environments that leverage head-mounted displays (HMDs). The HMDs allow users to freely change their field of view, enabling them to observe the virtual content similarly to how individuals experience the real world (Seymour et al., 2021). In addition, the head tracking feature of the HMDs synchronously projects users' movements and actions into the virtual environment. Finally, the HMDs fully immerse users into virtual experiences and hinder disruptions from the physical world. User interactions with the desktop environments, on the other hand, are not immune to disruptions (e.g., screen frames and desks comprise the physical space between a user and technology).

Thus, this study aims to answer the following questions:

1. *What technological factors of immersive environments enabled by HMDs are associated with users' spatial presence experiences, according to the existing studies?*
2. *What contextual factors of immersive environments enabled by HMDs are associated with users' spatial presence experiences, according to the existing studies?*
3. *What individual factors of users are associated with users' spatial presences experiences in immersive environments enabled by HMDs, according to the existing studies?*

In addition, we offer a research agenda that illustrates current gaps in both the extant literature and our understanding of the central role of spatial presence in immersive environments for the IS field.

Method

This study leveraged a concept-centric approach to conducting a literature review (Webster and Watson, 2002). The literature search was conducted in two rounds. First, we searched through various bibliographic databases, Google Scholar, and recognized academic journals in the fields of computer science, cognitive psychology, neuroscience, medicine, and management. We used a combination of various keywords (e.g., "space," "spatial," "telepresence," "physical presence," "virtual world") to retrieve relevant studies. Second, we focused specifically on the studies published in recognized IS journals and limited our search to the premier journals listed in the basket of eight. This round of search focused on identifying articles that focused on user experiences of presence by leveraging a variety of key words and combinations of key words (e.g., "virtual reality," "presence," "immersive," among others). In both pursuits, we focused on the studies published before 2022.

All studies were screened and assessed with the following inclusion criteria: (1) studies that identified factors associated with spatial presence, (2) studies that focused on immersive environments enabled by HMDs, and (3) studies that were published in English. In total, 34 studies were identified. Those studies were identified through the first round of searches. In the second search round (which focused on the premier IS journals), we did not identify any study that met our inclusion criteria. Studies focused on

immersive virtual environments did not specifically leverage HMDs and, therefore, did not meet our inclusion criteria.

Results

Table 1 summarizes the results of our review. In the following subsections, we discuss these factors in more detail.

Table 1: Contextual, Technological, and Individual Factors Affecting Spatial Presence

Contextual Factors	Technological Factors	Individual Factors

• Sensory cues:
  ○ Visual cues *(Mania and Robinson, 2005; Slater et al., 1995)*
  ○ Auditory cues *(Ma and Kaber, 2006)*
  ○ Olfactory cues *(Baus and Bauchard, 2017)*
• Point of view:
  ○ Physical position *(Bessa et al., 2018)*
  ○ First-person perspective *(Dahlquist et al., 2010; Borrego et al., 2020)*
• Engaging content:
  ○ Narrative story *(Gorini et al., 2011; Weech et al., 2020)*
  ○ Meaningful content *(Hoffman et al., 1998)*
  ○ Familiarity with the environment *(Viciana-Abad et al., 2004)*
  ○ Transitional environment *(Steinicke et al., 2010)*
  ○ Task complexity *(Slater et al., 1998; Ma and Kaber 2006; George et al., 2018)*
  ○ Interactions with virtual characters *(Steed et al., 2018; Kothgassner et al., 2018)*
	• Update rate (20 & 25 Hz) *(Barfield and Hendrix, 1995)*
	• Graphical realism *(Kwon et al., 2013)*
	• Stereoscopy *(Yun et al., 2012; Narciso et al., 2019)*
	• Synchronized visual content and auditory stimulation *(Gromer et al., 2019)*
	• Steering locomotion *(Clifton and Palmisano, 2020)*
		• Traits:
		  ○ Dissociative tendencies *(Murray et al., 2007)*
		  ○ Absorptive tendencies *(Murray et al., 2007; Kober and Neuper, 2013; Ling et al., 2013)*
		  ○ Immersive tendencies *(Kober and Neuper 2013; Ling et al., 2013; Wallach et al., 2010)*
		  ○ External locus of control *(Murray et al., 2007)*
		  ○ Openness *(Kober and Neuper, 2013)*
		  ○ Empathy *(Wallach et al., 2010; Ling et al., 2013)*
		• States:
		  ○ Anxiety and fear *(Regenbrecht et al., 1998; Riva et al., 2007; Price and Anderson, 2007; Alsina-Jurnet et al., 2011; Peperkorn et al., 2015)*
		  ○ Feeling of control *(Wei et al., 2019)*
		  ○ Emotions *(Riva et al., 2007)*
		• Abilities:
		  ○ Visual acuity *(Ling et al., 2013)*
		  ○ Visuospatial imagery ability *(Coxon et al., 2016)*
		  ○ Visual learning style *(Huang et al., 2019)*

Contextual Factors

Sensory Cues

Sensory cues, such as visual, auditory, and olfactory cues, can shape one's sense of spatial presence (Mania and Robinson, 2005; Slater et al., 1995; Ma and Kaber, 2006; Baus and Bauchard, 2017). ***Visual cues*** and, specifically, lighting properties, could enhance spatial presence. For instance, Mania and Robison (2005) found a positive correlation between illumination illusion (i.e., lighting properties of virtual objects) and spatial presence in the HMD monoscopic condition (i.e., when the content has been captured from a single

point of view rather than projecting different images to each eye). Further, Slater et al. (1995) found that the sense of presence increased after the subjects were exposed to dynamic shadows. The relationship was stronger for participants with visual dominance than those with auditory dominance. Moreover, the impact of ***auditory cues*** on spatial presence was explored in the study by Ma and Kaber (2006). Specifically, in the virtual environment emulating a basketball court, relevant auditory cues (such as the sound of a basketball bounce or cheering from observers) positively impacted spatial presence (Ma & Kaber 2006). In addition, ***olfactory cues*** (e.g., smells) were also explored in some immersive environments. For instance, Baus and Bauchard (2017) found that users' exposure to unpleasant smells in the virtual kitchen environment increased their sense of spatial presence. However, users' exposure to pleasant aromas did not significantly affect their perception of presence.

Overall, these findings align with the existing perspective on spatial presence that indicates that vividness (i.e., visual, auditory, and other characteristics of the content displayed) can be crucial for spatial presence experiences (Steuer, 1992).

Point of View

Several studies explored the point of view (specifically, the user's physical position and perspective in the immersive environments) in relation to spatial presence. The ***physical position*** of a participant positively impacts spatial presence, as shown in a study where participants had to ride a virtual bike while standing or sitting on top of a physical bicycle (in both cases, they were holding on to the physical handles of a bicycle while wearing a VR headset) (Bessa et al., 2018). Moreover, the ***first-person perspective*** in the immersive environment also positively affects the sense of spatial presence (Dahlquist et al., 2010; Borrego et al., 2020). These findings provides details to the existing theoretical perspective on the contextual information needed to induce spatial presence (Draper et al., 1998).

Engaging content

Engaging content (including immersive environments built around a narrative story, meaningful content, user's familiarity with the environment, transitional environment, and task complexity) could also impact spatial presence. Particularly, as demonstrated in theoretical studies on spatial presence (e.g., Draper et al., 1998), user's attentional resources directed towards specific stimuli in the virtual environment can evoke spatial presence. For example, the ***narrative*** (i.e., a sequence of events that users live through) about the environment is associated with an increased sense of spatial presence (Gorini et al., 2011; Weech et al., 2020). One study, for example, found that the narrative about a hospital was shown to induce higher emotional responses among participants, leading to a more heightened sense of spatial presence (Gorini et al., 2011). Moreover, Hoffman et al. (1998) conducted an experiment that involved a virtual chess game and found that ***meaningful content*** (meaningful chess positions as opposed to random chess positions) increased spatial presence. The level of expertise moderated the relationship – chess players experienced higher levels of presence when the content was meaningful (vs. meaningless positions).

In addition, users' ***familiarity*** with the immersive environment can also enhance spatial presence. Users familiar with the virtual environment content have a higher level of presence than users with no experience, in both stressful and not stressful environments (Viciana-Abad et al., 2004). Users with no prior experience with the virtual environment have a high sense of presence in stressful environments. Spatial presence can also be increased by implementing ***transitional environments*** (e.g., a person enters a virtual lab by first opening a door to the virtual lab replicated in the immersive environment) (Steinicke et al., 2010). Finally, ***task complexity*** (i.e., the degree of complicated actions needed to accomplish a task) was discussed in relation to a spatial presence in multiple studies (Slater et al., 1998; Ma and Kaber 2006; George et al., 2018). For example, through a randomized experiment, Slater et al. (1998) found a significant interaction between task complexity and gender. Spatial presence was higher for women in the more straightforward task but higher for men in the more complex task.

A few studies looked at ***user interactions with different types of virtual characters*** (e.g., agents and avatars) in immersive environments with respect to user experiences of spatial presence (Steed et al., 2018; Kothgassner et al., 2018). Responsiveness of virtual characters was found to be associated with an increasing spatial presence (Steed et al., 2018). Kothgassner et al. (2018), for instance, found that participants in the avatar condition (i.e., participants interacting with human-controlled virtual characters)

experienced higher levels of spatial presence than participants interacting with agents (i.e., computer-controlled virtual characters).

Technological Factors

Our literature search identified a series of technological factors that could impact spatial presence in immersive virtual environments and, therefore, clarified capabilities of immersive technologies that can evoke spatial presence (Steuer, 1992). ***Update rate*** (20 & 25 Hz) was found to affect spatial presence in the study conducted by Barfield and Hendrix (1995). Specifically, Barfield and Hendrix (1995) had subjects perform a search task within a virtual representation of the Stonehenge ruins while varying the update rate from 5 to 25 Hz in 5-Hz increments. The authors report that participants' sense of presence was significantly lower at 5 or 10 Hz than at 20 or 25 Hz. Furthermore, Kwon et al. (2013) studied the impact of ***graphical realism*** of virtual characters on presence in the context of a therapeutic intervention designed to reduce an individual's job interview anxiety. This research study indicates that presence increases with increasing graphical realism of virtual characters in the simulation.

Moreover, some studies explored the effect of ***stereoscopy*** (i.e., a technique that aims to create a sense of depth for an image) on spatial presence. Yun et al. (2012) studied the effects of stereoscopy on presence, anxiety, and cybersickness in the virtual public speaking setting (as a form of virtual reality exposure therapy). The authors found that stereoscopy does enhance spatial presence in the virtual environment but does not affect anxiety and cybersickness. On the other hand, Narciso et al. (2019) conducted a study in which participants explored a popular street celebration of Portugal and found no significant differences in presence under either a monoscopic or stereoscopic mode. However, when considering gender as a moderator, the stereoscopic condition had a higher effect on females' spatial presence than males in stressful environments. Conversely, males experienced higher levels of spatial presence in the monoscopic condition, leading the authors to speculate that gender differences in spatial ability may be behind these findings.

In the context of a virtual height simulation with participants who were afraid of heights, Gromer et al. (2019) conducted an experiment by means of manipulating fear in the participants (neutral vs. height condition) as well as sensory realism (high vs. low, by modifying both visual realism and auditory cues in the virtual environment). Results indicate that ***synchronized visual content and auditory stimulation*** induced higher emotional responses (fear) across acrophobic participants, which then led to a higher sense of spatial presence. Also, synchronized visual content and auditory stimulation impacted spatial presence.

Clifton and Palmisano (2020) found that ***steering locomotion*** (i.e., user's ability to initiate continuous simulated self-motion towards their desired destination in the immersive environment) was also associated with an increased sense of spatial presence. Notably, the authors found that the user experience of spatial presence increased over prolonged engagement with the steering locomotion feature. The effect was higher for females than for males.

Individuals Factors

Traits

Specific user characteristics can evoke spatial presence (Schubert et al., 1999; Sanchez-Vives and Slater, 2005; Wirth et al., 2007). Through our literature review, we identified specific traits that can associated with spatial presence. For instance, we found that personal tendencies, such as dissociative, absorptive, or immersive, can be linked to presence. ***Dissociative tendencies*** refer to individuals' tendencies to experience dissociative states that involve increasingly divided attentional resources, meaning that no stimulus receives more attentional resources than any other (Carleton et al., 2012). Murray et al. 2007 found a positive correlation between presence and dissociative tendencies. Furthermore, ***absorptive tendencies*** refer to the individual capacity, or inclination, to become fully engaged with a stimulus (Carleton et al., 2012). The correlation between spatial presence and one's absorptive tendencies was established in various studies in the past (Murray et al., 2007; Kober & Neuper, 2013; Ling et al., 2013). These relationships might be explained by the appearance of similarity between the components of presence and absorption, which occurs "when a single stimulus, or integrated group of stimuli, are focused on to the

exclusion of other external or internal stimuli" (Carleton et al., 2012, p. 2). A person with absorptive tendencies seems to be more likely to experience absorption. This person may commit their attentional resources to a specific stimulus within the VR, thereby ignoring external stimuli (external world, cybersickness, etc.), thus experiencing higher levels of presence within the virtual environment. In addition, ***immersive tendencies***, referring to individuals' tendency to become involved in various activities, were associated with spatial presence (Kober and Neuper, 2013; Ling et al., 2013; Wallach et al., 2010). Furthermore, ***external locus of control*** (the degree to which an individual feels like external forces control the events in their life) was associated with spatial presence experiences (Murray et al., 2007). ***Openness*** (i.e., how open-minded a person is to new experiences) and ***empathy*** (i.e., a tendency to be compassionate towards others) were also found to be associated with spatial presence experiences (Wallach et al., 2010; Kober & Neuper, 2013; Ling et al., 2013).

States

States (i.e., temporary feelings and emotions) were discussed in several studies concerning spatial presence. Specifically, some studies found that experiences of ***anxiety*** and ***fear*** in immersive environments can support a user's sense of spatial presence (Regenbrecht et al., 1998; Riva et al., 2007; Price and Anderson, 2007; Alsina-Jurnet et al., 2011; Peperkorn et al., 2015). For example, Alsina-Jurnet et al. (2011) studied students with high- and low-test anxiety in the virtual exam situation. They found a positive correlation between high test anxiety and spatial presence. Furthermore, users' ***feeling of control*** over events happening in the immersive environment was linked to higher levels of spatial presence among users (Wei et al., 2019). Specifically, Wei et al. (2019) found that in the context of the theme park, participants who reported a higher sense of control over virtual entities in the park experienced higher levels of presence. Moreover, a correlation between presence and ***emotions*** (either positive, such as happiness, or negative, such as sadness) depended on the context (Riva et al., 2007). For example, there is a positive correlation between presence and positive emotions in relaxing environments and a negative correlation between presence and negative emotions. On the other hand, there is a positive correlation between presence and negative emotions in stressful environments and a negative correlation between presence and positive emotions. More research is needed to untangle these findings and establish the direction of causality between these factors and presence.

Abilities

Some studies also considered individual abilities concerning their experiences of spatial presence (Ling et al., 2013; Coxon et al., 2016). For instance, Ling et al. (2013) found that ***visual acuity*** (i.e., sharpness of vision) is correlated with spatial presence. Further, Coxon et al. (2016) found that ***visuospatial imagery ability*** (i.e., individual ability to analyze space and visual forms) was shown to impact spatial presence in the context of a virtual train and a virtual city. Personal learning style (i.e., how individuals perceive and process information was also discussed in one study by Huang et al. (2019). The authors found that ***visual learning style*** (wherein individuals learn better by being exposed to information in images) is associated with higher levels of spatial presence in immersive environments.

Discussion

This study summarizes the current state of the art on factors affecting spatial presence in immersive environments. Our literature review captures a series of contextual, technological, and individual factors that can contribute to one's spatial presence experience in immersive environments. Our literature review indicates that sensory cues (visual, auditory, and olfactory) can affect spatial presence (Mania and Robinson, 2005; Slater et al., 1995; Ma and Kaber, 2006; Baus and Bauchard, 2017). However, it is unclear whether any specific sensory cue could contribute to spatial presence more than any other cue. Future studies should seek to understand the relative importance of sensory cues which can contribute to the optimal design of immersive technologies:

- What is the relative importance of various sensory cues (including visual, auditory, and olfactory) to spatial presence in immersive environments?

Furthermore, our review indicates that user familiarity with the content displayed in immersive environments can enhance spatial presence (Viciana-Abad et al., 2004). It is critical to understand how to support spatial presence in immersive environments that individuals are not familiar with. For example, the number of immersive applications for higher learning, medical training, and other areas keeps growing (Radianti et al., 2020, Fealy et al., 2019). Training could occur in unfamiliar virtual environments (e.g., letting medical students practice their newly acquired knowledge to perform a surgical procedure in the immersive environment). Future studies should, therefore, answer the following question:

- What are ways in which we can enhance spatial presence in immersive environments that users are unfamiliar with?

In addition, some studies did indicate that user interaction with virtual characters in immersive environments could contribute to spatial presence (Steed et al., 2018; Kothgassner et al., 2018). Exploring virtual characters' design (e.g., facial expressions and human likeness) in immersive environments presents another opportunity for future research. For instance, Seymour et al. (2021) indicate that users tend to exhibit stronger affinity and trust towards human-like virtual characters (compared to animated or cartoon-like characters). Thus, in line with this work, the following question should be answered in future research:

- What is the effect of facial expressions and human likeness of virtual characters on user experiences of spatial presence?

Furthermore, prior studies indicate that the findings regarding emotional states and various contexts in immersive environments are mixed (Riva et al., 2007). Therefore, future studies should untangle prior results and clarify the relationship between different emotions and users' spatial presence experience in different contexts. The following research question should be answered:

- What is the role of the virtual context in the relationship between user emotions and spatial presence in immersive environments?

Finally, some studies in this literature review were published in 1990s (e.g., Slater et al. (1995). Given the ongoing advances in the design of HMD-enabled immersive technologies, it can be critical to understand whether more recent technologies produce similar or different outcomes related to user experiences of spatial presence. For example, replication studies involving similar study design, but more advanced immersive technologies, should be conducted to explore whether the findings from the 90s still hold.

Conclusion

This study sheds light on factors affecting spatial presence in immersive technologies. Specifically, we identified a series of contextual, technological, and individual characteristics. In addition, we created a research agenda that informs researchers about the current gaps in the literature and provides a stimulus for future research on spatial presence. Our study can be a starting point towards a holistic understanding of spatial presence in immersive technologies that benefit the IS community.

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