Virtual Presence in Immersive Metaverse-enabling Environments: Being There, Being with Another, and Being the Actual Self

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Abstract:

Experiencing virtual presence can be associated with various positive outcomes in immersive metaverse-enabling environments. However, we do not adequately understand how to induce virtual presence in such environments, which can hinder users from fully benefiting from their interactions in the metaverse. To address this gap, we conducted a scoping review in which we examined empirical studies that focus on virtual presence in immersive metaverse-enabling environments and identified factors associated with various dimensions of presence (such as spatial presence, social presence, and self-presence). By analyzing relevant studies, we identified the critical factors that influence virtual presence in metaverse environments. In particular, we identified technological, contextual, and individual factors that contribute to the dimensions of virtual presence. We also derived preliminary design principles based on our analysis. Our design principles emphasize the importance of aligning virtual environments with users’ physical movements and stance, providing appropriate sensory cues, and enabling user interactions with virtual characters in inducing virtual presence. Overall, this study provides clarity on the factors that affect presence in immersive metaverse-enabling environments and offers insightful guidance for designing and evaluating such environments relative to virtual presence.

Keywords: Metaverse, Social Presence, Self-presence, Spatial Presence, Virtual Reality

Fiona Nah was the accepting senior editor for this paper.
1 Introduction

Many researchers see the concept of the metaverse, a multi-user environment that merges physical reality with digital virtuality, as the Internet’s next iteration (Mystakidis, 2022; Ng, 2022; Xu et al., 2022). This vision comprises various technologies, such as virtual reality (VR), digital twins, artificial intelligence (AI), and blockchain, to create a seamless, immersive, and interoperable shared ecosystem. The metaverse has the potential to revolutionize existing service ecosystems across domains from healthcare to education and beyond (Xu et al., 2022). For instance, one can use the metaverse to teach and train health workers (e.g., Veyond Metaverse) and, thereby, remove physical barriers and enable health workers to receive education in remote places.

Immersion, which VR technologies can enable, constitutes an essential metaverse characteristic (Mystakidis, 2022; Ng, 2022). Researchers generally define immersion as the extent to which technology can deliver an extensive, inclusive, surrounding, and vivid illusion of reality to users’ senses (Nilsson et al., 2016; Slater, 2003; Slater & Wilbur, 1997). The technology-supported, objective sensory fidelity that VR provides can lead to virtual presence, a subjective psychological response to the virtual environment (Makransky & Mayer, 2022; Slater, 2003). Studies recognize virtual presence as among the most salient among the myriad variables that reflect user experience quality in immersive environments (Clifton & Palmisano, 2019; Cummings & Bailenson, 2016; Oh et al., 2018). Indeed, one of the primary goals of immersive environments is to provide the experience of virtual presence to users.

Virtual presence generally encompasses three dimensions: spatial presence, social presence, and self-presence (Biocca, 1997). Spatial presence refers to a sense of “being there” and captures the extent to which a user perceives the virtual environment as real even though it is not (Hartmann et al., 2015). Social presence refers to a sense of being present with a “real” person in the virtual environment (Biocca, 1997). This definition implies user interactions with a mediated other (e.g., an avatar, agent, or something else). Finally, self-presence refers to “a state in which users experience their virtual self as if it were their actual self” (Tamborini & Skalski, 2006, pp. 226-227). For instance, users might feel as though their respective avatar’s body constitutes their actual body.

Studies report positive outcomes associated with user experience of different dimensions of virtual presence in the metaverse. For instance, a recent study found that achieving social presence in the metaverse can facilitate supportive interactions among young users and increase their social self-efficacy (Oh et al., 2023). Despite the potential benefits associated with achieving virtual presence in the metaverse, we do not adequately understand how to induce virtual presence in such environments. Existing information systems (IS) studies and reviews provide some insights into virtual presence (e.g., Schultze & Brooks, 2019; Nash et al., 2000; Schuemie et al., 2001; Schultze, 2010) but do not necessarily focus on environments with the immersion component (i.e., those that provide multi-sensory stimulation through technologies such as head-mounted displays (HMDs)) with respect to all dimensions of virtual presence. For instance, researchers have explored virtual presence in online desktop-based virtual worlds (e.g., Second Life) (Animesh et al., 2011; Davis et al., 2009; Franceschi et al., 2009; Nah et al., 2011; Saunders et al., 2011; Schultze, 2010; Schultze & Brooks, 2019; Srivastava & Chandra, 2018), recommendation systems (Qiu & Benbasat, 2009), computer-mediated communication tools (e.g., videoconferencing) (Chen, 2023; Altschuller & Benbunan-Fich, 2013; Sia et al., 2002; Yoo & Alavi, 2001; Zhang et al., 2007), enterprise systems (Subramaniam et al., 2013), and conversational agents (Gnewuch et al., 2022). If we do not sufficiently understand how to support and design for virtual presence in immersive metaverse-enabling environments, users similarly cannot realize the full benefits associated with user interactions with and in the metaverse.

To address this gap, we conducted a scoping review of the existing empirical studies that focus on virtual presence in immersive metaverse-enabling environments and identified various factors associated with virtual presence and its associated dimensions. Since immersion represents an essential metaverse characteristic that immersive technologies (e.g., HMDs) can enable, we first identified technological factors that can lead to virtual presence by answering the following question:

**RQ1:** Which technological factors contribute to immersion and result in enhanced virtual presence in immersive metaverse-enabling environments?

1 [https://www.veyondmetaverse.com/](https://www.veyondmetaverse.com/)
Even though virtual presence is a response to the immersion component, we also need to acknowledge that virtual presence can arise due to not only technological factors (which are superior in inducing immersion in immersive environments) but also specific individual factors (e.g., states, traits, and others) and contextual factors (i.e., related to the information displayed). For instance, researchers have found that empathy and psychological absorption can lead to virtual presence in environments that lack the immersion component (Sas & O’Hare, 2003). Yet, it remains unclear whether such and similar findings hold under the immersion component. Therefore, in our scoping review, we also investigated the individual and contextual factors that lead to enhanced virtual presence in the presence of the immersion component and, thus, address the following research questions:

**RQ2:** Which individual factors can contribute to enhanced virtual presence in immersive metaverse-enabling environments?

**RQ3:** Which contextual factors can contribute to enhanced virtual presence in immersive metaverse-enabling environments?

In addition to using our scoping review to answer our three research questions, we use our findings from the review to propose preliminary design principles for immersive metaverse-enabling environments and to develop a research agenda for future studies. Overall, our study provides clarity into factors associated with the virtual presence construct (and its associated dimensions) under the immersion component and guidance on designing and evaluating such environments with respect to virtual presence.

## 2 Background

### 2.1 Metaverse, Immersion, and Virtual Presence

Given that we primarily focus on the virtual presence construct and its associated dimensions in this study, we summarize the existing concepts related to it while highlighting the conceptual distinctions among them in this section. We summarize related concepts in Table 1.

**Table 1. Virtual Presence and Related Concepts**

| Concept                 | Definition                                                                                                                                 |
|-------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Metaverse               | A multi-user environment that merges physical reality with digital virtuality and comprises various technologies, such as VR, digital twins, AI, and blockchain (Mystakidis, 2022; Ng, 2022; Xu et al., 2022) |
| Immersion               | The extent to which technology can deliver an extensive, inclusive, surrounding, and vivid illusion of reality to a user’s senses (Nilsson et al., 2016; Slater, 2003; Slater & Wilbur, 1997) |
| Immersion component     | Multi-sensory stimulation provided through head-mounted displays (HMDs) or HMD-like technologies (Park & Kim, 2022; Mystakidis, 2022; Ng, 2022) |
| Immersive experiences   | Users’ exposure to the environment with the immersion component (Rodríguez-Ardura & Meseguer-Artola, 2018)                                      |
| Presence                | A neuropsychological phenomenon that involves referencing our perception of an external space beyond the limits of our sensory organs themselves (Riva et al., 2004) |
| Virtual presence        | A psychological state in which users experience virtual objects as actual objects in either sensory or non-sensory ways (Makransky & Mayer, 2022; Slater, 2003; Lee, 2004) |
| Telepresence (or spatial presence) | Mediated perception of an environment in which users are being transported via technologies (Steuer, 1992) |

The metaverse is a multi-user environment that merges physical reality with digital virtuality and comprises various technologies such as VR, digital twins, AI, and blockchain (Mystakidis, 2022; Ng, 2022; Xu et al., 2022). Given the advances in vision and language recognition based on deep learning and developments in space-convergence technologies (e.g., VR, Augmented Reality, etc.), the metaverse enables seamless interactions among users and virtual characters (Lee et al., 2021; Park et al., 2022). Further, the integration of multiple technologies (e.g., blockchain, AI, cloud computing) enables functions such as economic activities, real-time communication, and a perpetual virtual space (Wang et al., 2023). Head-mounted displays (HMDs) constitute essential hardware to support the metaverse (Park et al., 2022). HMDs provide multi-sensory stimulation by integrating technologies that stimulate multiple senses simultaneously. For
example, to deliver the visual component, one can use a high-resolution, stereoscopic display that presents 3D images with a wide field of view and allows users to perceive depth and spatial relationships as if in a real environment (Park et al., 2022; Harrison et al., 2010). To deliver auditory stimulation, one can use spatial audio systems that use directional sound to enhance how users perceive the virtual environment by making it possible to hear sounds coming from specific locations and distances in the virtual space. HMDs also use motion-track devices to project users’ movement in the virtual environment, incorporate feedback devices to simulate tactile sensations, and support auxiliary inputs, such as eye tracking, head tracking, and voice commands (Park et al., 2022). Through these various functionalities, HMDs can enable immersion, an essential metaverse characteristic (Mystakidis, 2022; Ng, 2022).

The concept of immersion has received multiple interpretations in various studies that focus on exploring virtual presence (Nilsson et al., 2016). There are four major views on immersion: immersion as a technology property, immersion as a perceptual response to that technology, immersion as a response to narrative, and immersion as a response to challenges that demand one use one’s intellect. The first view defines immersion as the extent to which technology can deliver an extensive, inclusive, surrounding, and vivid illusion of reality to a user’s senses (Nilsson et al., 2016; Slater, 2003; Slater & Wilbur, 1997). Essentially, this view considers immersion as an objectively measured technology property and not a user’s reaction to such technology. The other three views consider immersion as a user’s reaction to technology (Witmer & Singer, 1998; Nilsson et al., 2016; McMahon, 2013). In the metaverse, researchers consider immersion a technology property (e.g., Mystakidis, 2022; Ng, 2022). In alignment with our focus on the metaverse, we also view immersion in this way in our study.

Head-mounted displays (HMDs) or similar technologies typically facilitate environments with immersion components, which engage users through multi-sensory stimulation such as visual, auditory, and haptic feedback. These technologies create a seamless interaction and, thereby, enhance users’ sensory experience. Conversely, environments that lack immersion components often lead to disjointed experiences as elements such as screen frames and desks physically separate users from technology. An example would include 3D virtual worlds that users can access solely through desktop computers.

Users’ exposure to environments that include immersion components leads to immersive experiences. Virtual presence plays a central role in this immersive experience (Rodríguez-Ardura & Messeguer-Artola, 2018). Virtual presence builds on physical presence, which refers to an evolved bio-cultural mechanism, or on the neuropsychological phenomenon, which helps an individual to differentiate themselves from the external physical world (Riva et al., 2004). As prior studies have found, presence refers to perceiving an environment in a natural way (Steuer, 1992). While presence by itself does not specify any technological domain, virtual presence is technology-specific (i.e., it can be experienced through technology use) (Lee, 2004). Particularly, virtual presence is a psychological response to technology-mediated environments (Makransky & Mayer, 2022; Slater, 2003). It is a state in which virtual objects appear as actual through sensory and non-sensory means (Lee, 2004). The concept of virtual objects appearing as real can be explored through how users perceive virtual characters as real (i.e., social presence), perceive their virtual self as an extension of their physical body in the virtual environment (i.e., self-presence), and perceive virtual locations as real (i.e., spatial presence) (Biocca, 1997). Researchers have also termed spatial presence telepresence and used the two terms interchangeably (Steuer, 1992; Schubert, 2009). Specifically, it refers to users’ perception of an environment in which they experience a sense of being physically transported to the virtual environment through the mediation of technologies (Steuer, 1992).

In Section 2.2, we present various theoretical perspectives on the dimensions of virtual presence.

2.2 Theoretical Perspectives on Different Dimensions of Virtual Presence

Table 2 summarizes existing theoretical perspectives on the different dimensions of virtual presence.

| Presence dimension | Theoretical perspective | Summary |
|--------------------|-------------------------|---------|
| Spatial presence   | Attentional model of spatial presence (Draper et al., 1998) | Focuses on users’ attentional resources to virtual environment; more attention leads to stronger spatial presence |
|                    | Representational powers (Steuer, 1992) | Depends on vividness (sensory richness) and interactivity (user influence on environment) |
2.2.1 Spatial Presence

Various theoretical perspectives on spatial presence exist (Hartmann et al., 2015). For example, the attentional model of spatial presence recognizes spatial presence as a state that arises when users commit their attentional resources to contextual information in a virtual environment (Draper et al., 1998). The model states that the more attentional resources users devote to stimuli or context that a display presents, the stronger the sense of spatial presence (Draper et al., 1998). On the other hand, if users devote their attentional resources to the physical environment, they experience a weaker sense of presence in the virtual environment. While useful, this perspective does not address what motivates users to devote the necessary level of attentional resources to foster spatial presence (Hartmann et al., 2015).

Furthermore, according to Steuer (1992), spatial presence depends on technology’s representational powers, such as vividness and interactivity (Steuer, 1992). Vividness refers to technology’s capability to produce a sensory-rich mediated environment. Particularly, Steuer (1992) conceptualized vividness in terms of sensory breadth (i.e., presenting information across various senses) and sensory depth (i.e., quality of sensory information). Additionally, interactivity refers to the extent to which users can influence the virtual environment’s form and content. Interactivity captures speed (i.e., the rate at which a system can integrate users’ input into the environment), range (i.e., the number of possibilities in the environment), and mapping (i.e., a system’s ability to respond to users’ input naturally and predictably).

One of the most comprehensive theoretical perspectives on spatial presence, the two-level model of spatial presence (Wirth et al., 2007), extended prior views on spatial presence and explained this phenomenon via a two-step process. During the first step, users devote mental capacity (i.e., attention allocation) to the contextual information in the virtual environment. One can determine attention allocation via technology and user characteristics. This model echoes Steuer’s (1992) view on spatial presence by recognizing the importance of technology’s representational powers (i.e., interactivity and vividness) (Steuer, 1992). Further, user-directed attention allocation can depend on user traits, tendencies, and states (Wirth et al., 2007). Once users direct their attention toward the contextual information in the virtual environment, they can construct a spatial situation model, which is a mental model of the spatial layout of the environment. The accuracy and completeness of this spatial situation model depend on spatial cues (e.g., relative size, relative density, among others) in the virtual environment and relevant spatial memories and cognitions (e.g., spatial-visual imagery). Once users establish a spatial situation model, they can move to the experiential state of spatial presence. Yet, additional perceptual and cognitive processes should occur for users to achieve spatial presence. In particular, users can achieve spatial presence when they accept a virtual environment as a primary mental model of the world.

2.2.2 Social Presence

In reviewing theoretical perspectives on social presence, Triberti et al. (2018) identified various theories pertinent to understanding this phenomenon. The authors first describe “classic” theories on social presence that originated in the 1970s. For instance, Short et al. (1976) defined social presence in mediated conversations as a function of intimacy (i.e., the feeling of connectedness) and immediacy (i.e., the psychological distance between a user and their interactant) (Short et al., 1976). Similar to Short et al.’s
(1976) perspective, media richness theory (Draft & Lengel, 1986) implies that social presence is a function of the number of social cues that technology allows to transmit from one user to another (Triberti et al., 2018). Social cue richness (e.g., video combined with audio vs. text messaging) can enhance the user experience of social presence (Triberti et al., 2018).

Furthermore, the socio-constructivist approaches to understanding social presence view this phenomenon as a function of user characteristics rather than only technological characteristics (Triberti et al., 2018). In line with this approach, researchers have looked at users’ specific characteristics and behaviors concerning their experiences of social presence. For example, some studies linked users’ communicative acts (e.g., how they express feelings or humor) to social presence (Polhemus et al., 2001).

Modern theories refer to several factors associated with social presence (Triberti et al., 2018). For example, Biocca et al. (2003) state that social presence is a sensation that emerges as a result of sensory awareness (i.e., perceiving a mediated other through the senses), mutual awareness (i.e., a mediated other responding to a user), perceived access to intelligence (i.e., clues of intelligent behavior), the salience of interpersonal relationship (i.e., psychological connection), intimacy and immediacy, mutual understanding (i.e., comprehension of communicative acts), and behavioral engagement (i.e., interactivity) (Biocca et al., 2003). Even though Biocca’s theory provides insights into factors associated with social presence, it does not explain the mechanisms behind this phenomenon (Triberti et al., 2018). On the other hand, Riva’s (2008) perspective can explain such mechanisms. Users can achieve social presence when they recognize others’ intentions in the virtual environment. Exposure to cues (e.g., a door in the virtual environment was left open) can induce users to experience social presence even when they do not socially interact with others.

2.2.3 Self-presence

Currently, few theoretical perspectives explain self-presence. We found only one conceptual framework, which applies Damasio’s theory of consciousness (Damasio, 1999), to explain self-presence (Ratan, 2013; Ratan & Hasler, 2009; Ratan & Hasler, 2010). According to this framework, self-presence refers to “the extent to which some aspect of a person’s proto (body-schema) self, core (emotion-driven) self, and/or extended (identity-relevant) self is relevant during media use” (Ratan & Hasler, 2009, p. 14). Three layers (proto, core, and extended) constitute users’ experience of self-presence, and such layers align with Damasio’s three levels that form our consciousness (Damasio, 1999).

Proto presence refers to proprioception and awareness of an individual’s bodily orientation in the world. At the proto level (self vs. non-self), an individual’s differentiation from the external world occurs as the individual correctly couples perceptions and movements (Damasio, 1999; Riva et al., 2004). Researchers have defined users’ proto (body-schema) self-presence in virtual environments as “the extent to which a [user’s] mediated self-representation is integrated into body schema” (p. 325) (Ratan, 2013). When users achieve proto self-presence, mediated self-representations (e.g., avatars) become a physical extension of their body, and their awareness of the gap between themselves and technology dissipates.

Further, at the core level (self vs. present external world), individuals who differentiate themselves from the external world through proto presence actively synchronize with and respond to the external world (Damasio, 1999; Riva et al., 2004). Individuals can focus on sensory experiences around them and identify what is happening at the present moment. In virtual environments, the definition of self-presence at the core level emphasizes the role of users’ emotions. It captures “the extent to which mediated interactions between self-presentation and mediated objects cause emotional responses” (Ratan, 2013, p. 326).

Finally, at the extended level (a self relative to the present external world), individuals verify the significance of experienced events to themself in the external world (Damasio, 1999; Riva et al., 2004). Researchers have defined extended self-presence in virtual environments as the extent to which some aspects of a user’s mediated self-representations (e.g., avatars) reflect the user’s identity or specific elements of the user’s identity (Ratan, 2013). Self-presence is maximized when the three layers are closely aligned and is experienced as a unitary feeling (i.e., “a feeling of being in a world that exists outside of the self but in which the self is situated” (Riva et al., 2004, p. 414)).

3 Methods

We chose the scoping review methodology to map current research on virtual presence in the context of immersive metaverse-enabling environments. Scoping reviews “map rapidly the key concepts underpinning a research area and the main sources and types of evidence available” (Arksey & O’Malley, 2005, p. 194).
This method proves particularly useful for clarifying working definitions and exploring emerging topics (Tricco et al., 2015). To guide our review, we followed the framework that Arksey and O’Malley (2005) developed and the guidance from Joanna Briggs Institute (Peters et al., 2017). Given that the metaverse represents a new and developing research area, a scoping review represents the most appropriate approach to address our research questions.

### 3.1 Searching Strategy and Data Sources

We identified empirical studies that explored factors associated with virtual presence and, in particular, spatial presence, social presence, and self-presence. Our search encompassed all relevant studies published until May 2023. We searched for relevant keywords in various combinations, such as “presence”, “spatial presence”, “telepresence”, “virtual reality”, “social presence,” and “self-presence.”

We conducted two search rounds. In the first round, we identified literature published in peer-reviewed journals across various disciplines such as computer science, cognitive psychology, neuroscience, medicine, and management. We included journals such as *Electronics*, *Applied Sciences*, *JMIR Mental Health*, *BMC Medicine*, *Computers & Graphics*, and *Computers in Human Behavior*. Our search involved multiple databases, such as ProQuest, ACM Digital Library, AIS eLibrary, Scopus, and IEEE Digital Library. In the second round, our focus narrowed to studies in the IS field. We included IS journals listed in the Senior Scholars’ list of premier journals. This latter search led to no relevant papers.

### 3.2 Study Selection and Analysis

We identified 2,229 relevant studies in the first search round. We then manually screened and assessed each study’s abstract. We included studies that met the following specific criteria: 1) the study identified factors associated with spatial presence, social presence, or self-presence; 2) the study focused on environments with the immersion component (i.e., those that provide a multi-sensory stimulation through technologies such as head-mounted displays (HMDs)), which meant they could enable the metaverse; 3) the study appeared in a recognized journal related to various human-computer interaction aspects; and 4) the study used English. Notably, we excluded studies that focused on 3D virtual worlds that were enabled by desktops (i.e., environments without the immersion component). We also excluded studies that focused on stereoscopic displays but did not provide users with multisensory simulations.

In total, we excluded 2,098 papers in this screening round, which left 131 potentially relevant papers. Subsequently, we thoroughly read these 131 papers in full to further validate their relevance. We excluded studies that we could not access, such as workshop papers, commentaries, research-in-progress, abstracts and extended abstracts, and editorials. Additionally, we excluded studies that found statistically insignificant results to ensure we included factors with demonstrated relevance to and association with virtual presence. The threshold for statistical significance varied across studies in accordance with each study’s specifics, such as sample size, estimated effect size, and so on (Labovitz, 1968). In our selection process, we acknowledged these distinctive contextual elements by not applying a standard threshold for statistical significance across all studies. We based our decisions on the significance of the results according to each study’s significance thresholds. Hence, if a study determined its results as statistically insignificant based on its specific significance level, we did not include the results. Following this screening round, we excluded an additional 78 papers.

Ultimately, we arrived at a final sample with 53 relevant studies. Figure 1 summarizes our paper-selection process. We categorized factors into three distinct categories: technological factors, contextual factors, and individual factors.
Appendix A contains the papers’ descriptive information, such as their publication year and journal.

4 Results

4.1 Measures of Presence

While we identified some differences in how the studies in our final sample measured different presence dimensions, the measures exhibited common themes relative to the respective dimension. Spatial presence measures tended to focus on the extent to which users feel physically present in the virtual environment. Indeed, studies indicated that the presence questionnaire (Witmer et al., 1998) tends to generally correlate with Slater-Usoh-Steed questionnaire (Usoh et al., 2000) and ITC-presence questionnaire (Grassini & Laumann, 2020; Lessiter et al., 2001). Furthermore, studies indicated that the social presence measures tend to focus on evaluating the sense of connection and realism in virtual interactions (e.g., networked minds measure of social presence (Biocca et al., 2001) and the social presence survey (Bailenson et al., 2001)). Finally, studies indicated that self-presence measures exhibit commonalities with respect to assessing user’s perceived body ownership over a virtual representation. Table 3 maps the various presence measures that the studies in our sample reported.

| Presence dimension | Measures |
|--------------------|----------|
| Spatial presence   | The presence questionnaire (Witmer et al., 1998) focuses on the extent to which individuals experience being in one place or environment in addition to the influence of possible contributing factors. |
|                    | The Igroup presence questionnaire (Schubert et al., 2001) focuses on the sense of being physically present in the virtual environment, the attention devoted to the virtual environment, and the subjective experience of realism in the virtual environment. |
|                    | The Slater-Usoh-Steed questionnaire (Usoh et al., 2000) focuses on the sense of being in the virtual environment, the extent to which the virtual environment becomes the dominant reality, and the extent to which users remember the virtual reality as a place. |
|                    | The ITC-presence questionnaire (Lessiter et al., 2001) focuses on the sense of being there, the tendency to feel psychologically involved, the tendency to perceive the virtual environment as real, and adverse psychological reactions to the virtual environment. |
Table 3. Virtual Presence and Related Concepts

| Social presence | The networked minds measure of social presence (Biocca et al., 2001) focuses on the extent to which users believe that they are not alone in the virtual environment, the extent to which they allocate focal attention to others in the virtual environment, and the extent to which they believe that their actions are connected to the others in the virtual environment. |
| --- | --- |
| The social presence survey (Bailenson et al., 2001) focuses on the extent to which users believe that they are not alone in the virtual environment and the extent to which they believe that the other is real in the virtual environment. |
| Swinth and Blascovich’s (2001) questionnaire focuses on whether users feel observed, recognized, and directly engaged by virtual representations. |
| Guadagno et al.’s questionnaire (2007) focuses on users perceiving a virtual representation as realistic across four dimensions: the representation’s resemblance to a real person in action, movement, control by a human, and the overall sense of interacting with a real person. |

| Self-presentation | The embodiment of rubber hand questionnaire (Longo et al., 2008) focuses on the extent to which users feel that the rubber hand belongs to them, the extent to which users feel control over the rubber hand, the extent to which users feel that the rubber hand and their real hand are in the same location, and the extent to which users feel that the rubber hand has taken on features of their actual hand. |
| --- | --- |
| The embodiment questionnaire (Gonzalez-Franco & Peck, 2018) focuses on the sense of body ownership in a virtual environment, the perception of agency and motor control over virtual representations, the experience of tactile sensations that correspond to virtual interactions, and the alignment of one’s physical self with the virtual representation in terms of location and appearance. |
| The virtual embodiment questionnaire (Roth & Latoschik, 2020) focuses on the perceived body ownership over a virtual representation, the agency over a virtual representation, and the perceived change in the body schema. |
| Slater et al.’s (2010) questionnaire focuses on the intensity of embodied experiences and the perception of self-location and threat in a virtual environment. |
| Petkova and Ehrsson’s (2008) questionnaire focuses on the perceived body ownership over a virtual representation and the experience of tactile sensations that correspond to virtual interactions. |
| Anvari et al.’s (2023) questionnaire focuses on the perceived body ownership over a virtual representation and the perception of agency and motor control over virtual representations. |

4.2 Spatial Presence

Our literature review yielded contextual (involving virtual characters, position, engaging content), technological (grouped by vividness and interactivity) (Steuer, 1992), and individual (states, traits, abilities, and skills) factors. We group these factors and summarize high-level factors and subfactors relevant to each category in Table 4.
Table 4. Factors and Subfactors Associated with Spatial Presence

| Categories     | Factors                  | Subfactors                                                                 | Citations                                                      |
|----------------|--------------------------|-----------------------------------------------------------------------------|----------------------------------------------------------------|
| Contextual     | Virtual characters       | Interactions with virtual characters (avatars and agents)                   | Kothgassner et al. (2018), Steed et al. (2018)                  |
|                | Position                 | First-person perspective, standing position (vs. seated)                    | Borrego et al. (2019), Dahlquist et al. (2010), Queiroz et al. (2023) |
|                | Engaging content         | Task complexity, meaningful content, transitional environment, narrative about the environment, virtual reality spectatorship, non-bizarre elements, restorative environment | Denzer et al. (2022), Dillon & Cai (2022), Gorini et al. (2010), Hoffman et al. (1998), Li et al. (2022), Ma & Kaber (2006), Oh et al. (2022), Slater et al. (1998), Steinicke et al. (2010) |
| Technological  | Vividness                | Sensory cues (visual, auditory, tactile, and olfactory), stereoscopy (depth), and volume of graphical representations | Baus & Bouchard (2016), Chen et al. (2018), Chen et al. (2023), Gromer et al. (2019), Kwon et al. (2013), Ling et al. (2012), Ma & Kaber (2006), Mania & Robinson (2005), Narciso et al. (2019), Slater et al. (1995) |
|                | Interactivity            | Steering locomotion, hand-tracking function                                 | Chen et al. (2023), Cho et al. (2022), Clifton & Palmisano (2019) |
| Individual     | Traits                   | External locus of control, openness, empathy, dissociative tendencies, absorptive tendencies, and immersive tendencies | Dillon & Cai (2022), Kober & Neuper (2013), Ling et al. (2013), Murray et al. (2007), Wallach et al. (2010) |
|                | States                   | Sense of control, anxiety, fear, and sadness                               | Alsina-Jurnet et al. (2011), Mayer et al. (2022), Peperkorn et al. (2015), Price & Anderson (2007), Regenbrecht et al. (1998), Riva et al. (2007), Wei et al. (2019) |
|                | Abilities and skills      | Visual acuity, visuospatial imagery ability, visual learning style, video game experience | Coxon et al. (2016), Huang et al. (2020), Ling et al. (2013), Maneuverier et al. (2020) |

4.2.1 Contextual Factors Associated with Spatial Presence

Several studies reported that user interactions with virtual characters (including agents, defined as computer-controlled entities, and avatars, defined as human-controlled entities) could be associated with spatial presence (Kothgassner et al., 2018; Steed et al., 2018). Particularly, Steed et al. (2018) found that virtual characters’ responsiveness (i.e., virtual characters’ reactions to users’ actions) can lead to spatial presence. Furthermore, Kothgassner et al. (2018) found that participants who interacted with avatars generally experienced higher levels of spatial presence than participants who interacted with agents. They also identified a significant interaction between agency and users’ gender in that females experienced spatial presence at higher levels than males. In understanding these findings, we can see that virtual characters represent a contextual element that consumes users’ attentional resources in the virtual environment and, thereby, induce spatial presence (Draper et al., 1998).

Furthermore, some studies discussed users’ position (Borrego et al., 2019; Dahlquist et al., 2010; Queiroz et al., 2023). For instance, some studies explored the role of a first-person perspective (i.e., the experience of virtual content from a spatial origin with a direction) in spatial presence experiences. Borrego et al. (2019) conducted an experiment that involved squashing a pink playdough item from the first- versus third-person perspective and found that users experienced greater spatial presence from the first-person perspective. Similarly, in their study, Dahlquist et al. (2010) explored the role of the first-person perspective concerning spatial presence and pain tolerance. They found that the first-person perspective enhanced spatial presence but did not affect pain tolerance. Through evolution, the human perceptual system has been tuned to perceive the real world (Steuer, 1992). Thus, it makes sense that appealing to the same perceptual mechanisms (e.g., a first-person perspective) in the virtual environment can enhance the degree to which users experience spatial presence.
Studies also empirically identified different elements of engaging content that also increase spatial presence (Denzer et al., 2022; Dillon & Cai, 2022; Gorini et al., 2010; Li et al., 2022; Hoffman et al., 1998; Ma & Kaber, 2006; Oh et al., 2022; Slater et al., 1998; Steinicke et al., 2010). Such elements include task complexity, meaningful content, transitional environment, narrative about the virtual environment, virtual reality spectatorship, non-bizarre elements, and restorative environment. Slater et al. (1998) and Ma and Kaber (2006) explored task complexity (the degree of complicated actions needed to complete a task). For example, Slater et al. (1998) found a significant interaction between task complexity and gender through a randomized experiment. In particular, women exhibited higher spatial presence in a more straightforward task, whereas men exhibited higher spatial presence in a more complex task. Similarly, Ma and Kaber (2006) found a positive relationship between task complexity and spatial presence in a basketball game context. Given that complex tasks require users’ attention, we do not find it surprising that studies have found an association between task complexity and spatial presence. The attentional model of spatial presence explains such findings in asserting that users can experience greater spatial presence when committing attentional resources to specific contextual information (Draper et al., 1998).

Additionally, Hoffman et al. (1998) explored meaningful content (i.e., relevance or usefulness of the content to its users) in relation to spatial presence. Specifically, the authors conducted an experiment that involved a virtual chess game. They found that meaningful chess positions (i.e., one might encounter in a typical chess game), as opposed to random chess positions, increased spatial presence. Expertise level moderated the relationship: accomplished chess players experienced higher spatial presence with meaningful positions (vs. meaningless positions). They also found an interaction between expertise level and what chess positions mean: non-chess players showed no significant difference between meaningful and meaningless positions (unlike chess players).

In addition, narratives about the virtual environment (i.e., a series of events that users actively experience) enhance spatial presence. For example, Gorini et al. (2011) found that a narrative about a hospital (i.e., a story about the events in the hospital) induced higher emotional responses among participants, which led to a more heightened sense of spatial presence. Similarly, Oh et al. (2022) found virtual reality spectatorship in a sports game context to enhance spatial presence. Denzer et al. (2022) also found that realistic, non-bizarre elements can enhance spatial presence in virtual environments. They compared virtual environments resembling office environments with bizarre elements, such as disappearing text in an open textbook, pens growing to an unrealistic size, and other changes that typically cannot happen in real life.

Finally, Steinicke et al. (2010) found an association between transitional environments (i.e., gradual transition from the real world into the virtual environment) and spatial presence. Steinicke et al. (2010) experimented wherein a person enters a virtual lab by first opening a door to the virtual lab replicated in the virtual environment.

### 4.2.2 Technological Factors Associated with Spatial Presence

Vividness refers to the factors that capture technology’s capability to produce a sensorial rich mediated environment (Steuer, 1992). Multiple studies have found that sensory cues—which refer to visual, tactile, olfactory, gustatory, or auditory stimuli that evoke a response or behavior—can trigger spatial presence (Baus & Bouchard, 2016; Bessa et al., 2018; Chen et al., 2023; Ma & Kaber, 2006; Mania & Robinson, 2005; Slater et al., 1995). For example, several studies have found an association between visual cues, such as illumination illusion (i.e., lighting properties of virtual objects) and dynamic shadows, and spatial presence (Mania & Robinson, 2005; Slater et al., 1995). Mania and Robinson (2005) found a positive correlation between illumination illusion and spatial presence in the HMD monoscopic condition. In this condition, the content was captured from a single point of view rather than using technology to project different images to each eye. Further, Slater et al. (1995) found that the sense of spatial presence increased after they exposed subjects to dynamic shadows. The relationship was stronger for participants with visual dominance than for participants with auditory dominance.

In their study, Ma and Kaber (2006) explored the impact of auditory cues on spatial presence. Specifically, in a virtual environment that emulated 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, researchers have explored olfactory cues (e.g., smells) in immersive metaverse-enabling environments. For instance, Baus and Bauchard (2016) found that users’ exposure to unpleasant smells in the virtual kitchen environment increased their sense of spatial presence. However, their exposure to pleasant aromas did not significantly affect their perception of spatial presence. It is unclear why pleasant and unpleasant smells produce different results in terms of spatial presence, and future studies should
explore the mechanisms behind the results in more detail. Finally, Bessa et al. (2018) examined tactile cues (i.e., cues involving physical touch). Specifically, they conducted a study in which participants had to ride a virtual bike while standing or sitting on a physical bicycle. They found that the physical position that aligned with the content displayed in the virtual environment (e.g., holding on to the physical handles of a bike while wearing an HMD headset) could positively impact spatial presence. Gromer et al. (2019) also discussed synchronicity between sensory cues (e.g., synchronized visual and auditory simulation) as a factor that can support the user experience of spatial presence.

Finally, spatial presence requires sufficient depth (i.e., stereoscopy) and volume of graphical representations (Kwon et al., 2013; Ling et al., 2012; Narciso et al., 2019). For example, Ling et al. (2012) studied the effects of stereoscopy on presence, anxiety, and cybersickness in the virtual public speaking setting (as a virtual reality exposure therapy) and found that stereoscopy enhanced spatial presence in the virtual environment. On the other hand, Narciso et al. (2019) conducted a study in which participants explored a popular street celebration in Portugal and found no significant difference in spatial presence under either a monoscopic or stereoscopic mode. However, when considering gender as a moderator, the stereoscopic condition had a higher effect on females than males in stressful environments. Conversely, males experienced greater spatial presence in the monoscopic condition, which led the authors to speculate that gender differences in spatial ability may have caused these findings.

Furthermore, interactivity factors generally capture speed (i.e., the rate at which a system can integrate the user input into the environment), range (i.e., the number of possibilities in a virtual environment), and mapping (i.e., response to users’ input naturally and predictably) (Chen et al., 2023; Steuer, 1992). Clifton and Palmisano (2019) found an association between steering locomotion (i.e., users’ ability to initiate continuous simulated self-motion towards their desired destination in an immersive environment) and an increased sense of spatial presence. Notably, they found that the user experience of spatial presence increased over prolonged engagement with the steering locomotion feature. This effect was higher for females than for males. Finally, Cho et al. (2022) found that including a hand-tracking function enhanced the user experience of spatial presence.

### 4.2.3 Individual Factors Associated with Spatial Presence

Prior studies have found a relationship between various individual traits, such as external locus of control, openness, empathy, dissociative tendencies, absorptive tendencies, immersive tendencies, and spatial presence (Kober & Neuper, 2013; Ling et al., 2013; Murray et al., 2007; Wallach et al., 2010). In the virtual city context, Murray et al. (2007) conducted an experiment that involved students and found an association between various psychological constructs that involved external locus of control (i.e., the degree to which an individual feels like external forces control the events in their life) and spatial presence experiences. The authors found that the more people are open to new experiences, the stronger their experiences of presence. Furthermore, Kober and Neuper (2013) found a link between openness (i.e., curiosity and imaginative and insightful behavior) and spatial presence.

Ling et al. (2013) found that participants feeling compassion and concern for others tend to experience spatial presence in the virtual environment with avatars. Similarly, both Ling et al. (2013) and Wallach et al. (2010) found an association between empathy (i.e., a tendency to be compassionate towards others) and spatial presence. Wallach et al. (2010) explained such a relationship by viewing empathy as a form of an emotional projection and viewing presence as an emotional connection to a place (as opposed to the cognitive recognition of the place). Empathy can strengthen the bond between participants and their virtual environment as an emotional projection.

Studies also found an association between spatial presence experiences and various tendencies that involve dissociative tendency, immersive tendency, and absorptive tendency (Kober & Neuper, 2013; Ling et al., 2013; Murray et al., 2007; Wallach et al., 2010). Dissociative tendencies refer to individuals’ proclivity to experience dissociative states that involve increasingly divided attentional resources, which means that no stimulus receives more attentional resources than any other (Carleton et al., 2012). Murray et al. (2007) found a positive correlation between spatial presence and dissociative tendencies. The authors explain their findings by referring to prior studies that indicate individuals with high dissociative tendencies forget about the physical world and experience the virtual environment as real compared to those with low dissociative tendencies. Moreover, several studies found an association between immersive tendencies (individual tendencies to become involved in various activities) and spatial presence (Dillon & Cai, 2022; Kober & Neuper, 2013; Ling et al., 2013; Wallach et al., 2010). We do not view these findings as surprising given that research has found an association between immersive tendencies and people becoming involved in
certain activities and feeling deeply engaged in virtual environments (Kober & Neuper, 2013). Further, individuals with immersive tendencies tend to ignore external distractions and focus on their virtual experiences (Wallach et al., 2010). Individuals with lower immersive tendencies tend to have less developed spatial abilities that may prevent them from generating a mental representation of mediated virtual environments (Ling et al., 2013). Research has also found absorptive tendencies to strongly predict spatial presence (Kober & Neuper, 2013). Absorptive tendencies refer to devoting one’s total attention to something (Tellegen & Atkinson, 1974). These tendencies can also involve focusing attentional resources on a specific part of reality (e.g., virtual environment) and ignoring other aspects of reality (e.g., the physical world) (Kober & Neuper, 2013).

Several studies also discussed various individual states (e.g., sense of control, anxiety, fear, and sadness) in relation to spatial presence (Alsina-Jurnet et al., 2011; Mayer et al., 2022; Peperkorn et al., 2015; Price & Anderson, 2007; Regenbrecht et al., 1998; Riva et al., 2007; Wei et al., 2019). For instance, a sense of control refers to the perception that one has control over entities in the virtual environment (Wei et al., 2019). In a theme park context, Wei et al. (2019) found that participants who reported having more control over virtual entities in the park experienced greater spatial presence. They explained their findings by referring to the theory of flow, which indicates that a sense of control plays a critical role in flow experience that might be associated with a sense of presence.

In addition, anxiety and fear are associated with spatial presence (Alsina-Jurnet et al., 2011; Mayer et al., 2022; Peperkorn et al., 2015; Price & Anderson, 2007; Regenbrecht et al., 1998; Riva et al., 2007). For instance, Price and Anderson (2007) conducted an experiment that involved individuals with agoraphobia (i.e., a fear of heights). They found that spatial presence moderated the relationship between pre-treatment and in-session anxiety in the virtual environment. Moreover, Alsina-Jurnet et al. (2011) studied students with high- and low-test anxiety in a virtual exam situation and found a positive correlation between test anxiety and participants’ experiences of spatial presence.

Studies also explored fear in relation to spatial presence (Peperkorn et al., 2015; Regenbrecht et al., 1998). For example, Peperkorn et al. (2015) found that spatial presence can affect the degree to which participants fear spiders in virtual environments with spiders. Over time, however, fear and spatial presence become mutually dependent on each other. Overall, participants’ responses to the phobic elements and feared stimuli that they perceive as real in the virtual environment may explain the association between spatial presence and anxiety or fear.

Moreover, Riva et al. (2007) conducted a study to explore the relationship between spatial presence and emotions (negative, such as fear and sadness, and positive, such as happiness). They found the relationship between emotions and spatial presence depends on the context. For example, in relaxing environments, they found a positive correlation between presence and positive emotions and a negative correlation between presence and negative emotions. On the other hand, in stressful environments, they found a positive correlation between presence and negative emotions and a negative correlation between presence and positive emotions. We need more research that untangles these findings and explains how context and emotions lead to spatial presence.

In addition, studies report an association between spatial presence and specific user abilities and skills, such as visual acuity, visuospatial imagery ability, visual learning style, and video game experience (Coxon et al., 2016; Huang et al., 2020; Ling et al., 2013; Maneuvrier et al., 2020). Studies have linked visual acuity, which refers to vision sharpness, to spatial presence. Ling et al. (2013) conducted several experiments and found a positive correlation between the visual acuity of the right (or dominant) eye and spatial presence. Further, Coxon et al. (2016) found that visuospatial imagery ability (i.e., individual ability to analyze space and visual forms) impacted spatial presence in a virtual train and a virtual city context. In addition, Huang et al. (2020) also discussed learning style (i.e., how individuals perceive and process information). They found an association between the visual learning style (wherein individuals learn better after exposure to information in images) and greater spatial presence in immersive environments.

Finally, Maneuvrier et al. (2020) explored prior video game experience and found that it can predict the degree to which users experience spatial presence. Individuals with video game experience may be more susceptible to presence because they have had a chance to enhance their familiarity with interacting with computers. Their familiarity with computer interaction could make it easier for them to facilitate ergonomics processes and recognize their cognitive scheme in virtual environments, which could lead them to experience greater spatial presence. Video games could also possibly train users to become more focused on virtual entities and ignore the physical world, which plays a critical role in inducing spatial presence.
4.3 Social Presence

Based on our literature review, we identified various contextual (virtual characters and point of view), technological (graphical and behavioral realism of virtual characters), and individual (states, traits, and perceptions) factors. We summarize high-level factors and subfactors relevant to each category in Table 5.

Table 5. Factors and Subfactors Associated with Social Presence

| Categories    | Factors                          | Subfactors                                                                                     | Citations                        |
|---------------|----------------------------------|-----------------------------------------------------------------------------------------------|----------------------------------|
| Contextual    | Virtual characters               | Interactions with virtual characters (avatars and agents)                                     | Erickson-Davis et al. (2021),    |
|               |                                  |                                                                                               | Kothgassner et al. (2018),       |
|               |                                  |                                                                                               | Voinea et al. (2022), Yuan & Gao |
|               | Point of view                    | Independent viewpoint                                                                         | Minghao & Jiro (2019)            |
| Technological | Graphical realism of virtual    | The depth and volume of graphical representations                                             | Bailenson et al. (2005), Kwon et |
|               | characters                       |                                                                                               | al. (2013)                       |
|               | Behavioral realism of virtual    | Natural movements of virtual characters                                                        | Bailenson et al. (2005), Guadagno |
|               | characters                       |                                                                                               | et al. (2007)                    |
| Individual    | Traits                           | Absorptive tendencies                                                                         | Erickson-Davis et al. (2021)     |
|               | States                           | Paranoia, loneliness, detachment, recognition of self, sense of familiarity                    | Riches et al. (2019)             |
|               | Perceptions                      | Empathy                                                                                       | Guadagno et al. (2011)           |

4.3.1 Contextual Factors Associated with Social Presence

The studies we reviewed discussed a limited number of contextual factors. In collaborative multi-user HMD technologies, users with independent viewpoints, which means they can navigate freely in the virtual environment and be exposed to different views of the shared world based on their movements, reported greater social presence and improved communication efficiency (Minghao & Jiro, 2019). The authors attributed these findings to shared awareness between users and mutual non-verbal communication in the shared environment.

Further, several studies found that user interactions with virtual characters (i.e., agents and avatars) can also enhance social presence (Erickson-Davis et al., 2021; Kothgassner et al., 2018; Voinea et al., 2022; Yuan & Gao, 2023). For instance, Erickson-Davis et al. (2021) found that responsive virtual characters better evoked a sense of social presence in the virtual environment than verbal language alone. This finding aligns with Biocca et al.’s (2003) theoretical perspective on the important role that behavioral engagement (i.e., interactivity) elements play in supporting social presence. Similarly, in the virtual café setting, participants interacting with avatars experienced greater social presence (Kothgassner et al., 2018). They also identified significant interactions between agency and gender such that females experienced more social presence when interacting with avatars than with agents. It remains unclear why the avatar condition led to a higher social presence among females. It might be possible that under the avatar condition, users can recognize others’ intentions more easily (Riva, 2008) than under the agent condition.

4.3.2 Technological Factors Associated with Social Presence

Two studies found that virtual characters can support social presence (Erickson-Davis et al., 2021; Kothgassner et al., 2018). Additional studies explored specific virtual character characteristics that can facilitate users’ sense of social presence. These characteristics describe two significant technological aspects associated with the virtual characters in immersive metaverse-enabling environments: graphical realism (Bailenson et al., 2005; Kwon et al., 2013) and behavioral realism (Bailenson et al., 2005; Guadagno et al., 2007).

Graphical realism refers to the depth and volume of graphical representations (i.e., cartoon-like vs. realistic virtual characters) (Kwon et al., 2013). Kwon et al. (2013) investigated therapeutic interventions designed to reduce job interview anxiety through exposure and found that increasing the graphical realism of virtual characters (i.e., interviewer) increased users’ sense of social presence and anxiety. Furthermore, Bailenson et al. (2005) found that graphically realistic virtual characters (and specifically agents) can elicit user responses that would be appropriate only in situations with an actual human (e.g., feeling embarrassed).
Bailenson et al. (2005) also explored the impact of behavioral realism, defined as random and natural movements of virtual characters (as opposed to static and unnatural movements), on social presence. Indeed, the authors found greater social presence in the random-movement agent condition than in the static condition. Guadagno et al. (2007) further expanded the findings on behavioral realism by conducting experiments where they manipulated behavioral realism via alteration of agents’ facial expressions (e.g., gaze, head movements, and lip movements). They found that greater behavioral realism enhanced the extent to which users experience social presence.

Interestingly, the authors also found that users experienced more social presence when they believed that virtual characters were avatars rather than agents. Even though these findings make sense intuitively (e.g., humans control avatars, so they may act more naturally than agents and, thereby, make users perceive avatars as more real and experience social presence), existing theoretical perspectives on social presence do not delineate these technological aspects of virtual characters. Overall, one needs to consider the behaviors and appearances of virtual characters and make them align with the behaviors and impressions of people in the real world to facilitate social presence.

4.3.3 Individual Factors Associated with Social Presence

Erickson-Davis et al. (2021) found an association between absorptive tendencies and the user experience of social presence. In particular, they conducted an experiment to explore the effects of active imagination in creating a sense of the presence of an ambiguously real other by leveraging immersive environments with avatars. They found that absorptive tendencies lead to higher levels of social presence among participants. We do not view this finding as surprising as individuals with absorptive tendencies tend to focus their attentional resources on a specific part of reality (e.g., an avatar) and ignore the other aspects (Kober & Neuper, 2013). Thus, in immersive environments with avatars, individuals with absorptive tendencies might focus on their interactions with avatars and, thereby, foster the senses of intimacy and immediacy that can lead to social presence (Short et al., 1976).

Riches et al. (2019) also conducted a qualitative study and identified various individual states associated with social presence. They found that participants’ feelings of detachment decreased social presence in a virtual bar, while paranoia and loneliness increased social presence. In addition, participants’ sense of familiarity with the immersive environment (or certain elements thereof) increased social presence. Moreover, participants who recognized that their responses to virtual characters resembled their responses to humans in real life also indicated greater social presence. Given this study’s qualitative nature, future research should build hypotheses based on Riches et al.’s (2019) findings and test them empirically to establish a causal link.

Finally, perceived empathy of virtual characters can lead to enhanced social presence (Guadagno et al., 2011). Guadagno et al. (2011) conducted an experiment that involved female participants interacting with a “peer counselor.” Participants who perceived the peer counselor as more empathetic led participants to view their counselor as more supportive, which, in turn, increased their comfort and satisfaction levels in addition to social presence. This finding seems to align with Biocca et al.’s (2003) theoretical perspective on social presence, which indicates that the salience of interpersonal relationships (i.e., a psychological connection) between users and virtual characters can enhance users’ sense of social presence.

4.4 Self-presence

Our literature review yielded a handful of studies that explored factors associated with self-presence in immersive metaverse-enabling environments. We summarize the results in Table 6.
4.4.1 Technological Factors Associated with Self-presence

Petkova and Ehrsson (2008) found that synchronized visual and tactile stimulation can increase self-presence. They conducted experimental manipulations that involved participants seeing a virtual body from the first-person perspective while subjected to a synchronized visual and tactile stimulation. In this experiment, the researchers positioned two cameras on a male mannequin to record the view from the mannequin’s first-person perspective. Participants wore an HMD connected to the cameras so that participants could see the images from the left and right video cameras on the mannequin. The researchers used a short rod to repetitively stroke the participants’ actual abdomen (beyond their view) in synchrony with identical strokes applied to the mannequin’s abdomen (that participants could observe via the HMD). After the experiment, participants reported their feeling of self-presence under the synchronous condition. Under the asynchronous control condition, they did not report self-presence.

Moreover, Leonardis et al. (2014) studied the effect of multisensory feedback on the sense of self-presence during a walking experience. They found that vestibular and proprioceptive feedback, which involves a motion-based platform that provides illusory leg movements and changes a participant’s angle in response to walking velocity, increases the sense of self-presence in a walking task compared to a static condition.

4.4.2 Contextual Factors Associated with Self-presence

Steed et al. (2018) found an association between self-presence and user interactions with virtual characters that represent part of the external world in the virtual environment (Steed et al., 2018). When users could interact with virtual characters and receive a response from them, self-presence moderately influenced the illusion of being in a real place. In the future, researchers could expand this study to explore the relationship between self-presence and other aspects of the “external world”. Also, studies found that similarities between a virtual character (e.g., an avatar) and a user can enhance self-presence (Radiah et al., 2023; Suk & Laine, 2023). For instance, Radiah et al. (2023) found that personalized same-gender avatars elicited greater self-presence among participants compared to the non-personalized condition.

Similarly, Petkova and Ehrsson (2008) conducted various experiments to identify conditions under which individuals would experience self-presence. In one experiment, they examined whether a human-like virtual body would encourage users to experience self-presence. They found an association between self-presence and virtual human-like body parts (e.g., a virtual hand extending from the user’s spatial origin). In addition, they found an association between displaying a user’s upper body in the virtual environment with greater self-presence (Anvari et al., 2023). Finally, a first-person perspective can also support self-presence (Borrego et al., 2019; Slater et al., 2010).

4.4.3 Individual Factors Associated with Self-presence

Only one study provided insights into the emotional reactions that could support self-presence. Petkova and Ehrsson (2008) conducted an experiment that threatened users’ virtual body with a knife cut across its abdomen. The researchers assessed skin conductance response as a way to measure anxiety and found a relationship between the degree of stress and self-presence. We need more research to untangle these findings and explain their mechanisms.
5 Discussion

In our study, we consolidated empirical evidence on the technological, individual, and contextual factors affecting virtual presence in immersive metaverse-enabling environments. Our study holistically overviews factors associated with virtual presence. We summarize our findings and highlight (in bold) factors common across two or more dimensions of virtual presence in Table 7.

| Table 7. Summary of Findings |
|-----------------------------|
| **Technological** | **Contextual** | **Individual** |
| Volume of graphical representations* | Volume of graphical representations* | Synchronized visual and tactile stimulation |
| Depth of graphical representations | Sensory cues | Vestibular and proprioceptive feedback |
| Natural movements of virtual characters | Stereoscopy | |
| | Update rate | |
| | Steering locomotion | |
| | Hand-tracking function | |
| | Independent viewpoint | First-person perspective* |
| | Interactions with virtual characters* | Interactions with virtual characters* |
| | | Standing position |
| | | Task complexity |
| | | Meaningful content |
| | | Transitional environment |
| | | Virtual reality spectatorship |
| | | Non-bizarre elements |
| | | Restorative environment |
| | Negative emotions \(\text{paranoia, loneliness, detachment}\)* | Negative emotions \(\text{anxiety, fear, sadness}\)* |
| | Absorptive tendencies* | Absorptive tendencies* |
| | Empathy* | Empathy* |
| | Recognition of self | External locus of control |
| | Sense of familiarity | Openness |
| | | Dissociative tendencies |
| | | Immersive tendencies |
| | | Sense of control |
| | | Visual acuity |
| | | Visuospatial imagery ability |
| | | Visual learning style |
| | | Video game experience |

Note: * Factors common across two or more presence dimensions

In Sections 5.1 to 5.3 we discuss different types of factors with respect to their uniqueness to each dimension of virtual presence as well as to the virtual environment’s immersion. Furthermore, we propose preliminary design principles based on the identified factors and a research agenda to guide future studies on virtual presence in immersive metaverse-enabling environments.

5.1 Technological Factors Affecting Virtual Presence in Immersive Metaverse-enabling Environments

As Table 7 shows, nearly every technological factor represents a unique specific dimension of virtual presence. The volume of graphical representations that can impact both social presence and spatial presence represents the only notable exception (Baiienson et al., 2005; Kwon et al., 2013). One can attribute this shared factor to the importance of the realism level necessary to convince the brain about virtual characters’ authenticity (for social presence) and spatial forms (for spatial presence) in virtual environments.

Beyond this shared factor, each technological factor aligns closely with real-world standards and norms relevant to the respective dimension of virtual presence. For instance, social presence centers around perceiving and interacting with others. In virtual environments, perceiving and interacting with others requires virtual characters to not only exhibit a high degree of graphical realism (Baiienson et al., 2005; Kwon et al., 2013) but also to behave naturally and in ways that concur with real-world expectations (Baiienson et al., 2005; Guadagno et al., 2007). This alignment plays a crucial role in underpinning users’ ability to perceive and interact with the virtual characters in a manner akin to real-life interactions.
Furthermore, technological factors associated with spatial presence capture sensory cues, stereoscopy, steering locomotion, and hand-tracking feature (Baus & Bouchard, 2016; Bessa et al., 2018; Chen et al., 2023; Gromer et al., 2019; Kwon et al., 2013; Ling et al., 2012; Ma & Kaber, 2006; Mania & Robinson, 2005; Narciso et al., 2019; Slater et al., 1995; Cho et al., 2022; Clifton & Palmisano, 2019). These factors indicate the importance of replicating real-world dynamics to induce spatial presence (e.g., experiencing something akin to slow motion, which equates to a slow update rate in the virtual environment, would be disruptive in the real world).

Lastly, self-presence pertains to synchronization between stimulation and feedback as it pertains to users' body in virtual environments (Petkova & Ehrsson, 2008; Leonardis et al., 2014). In the real world, people make body movements (e.g., raising a hand) instinctively (unless a medical condition or something else impedes them). The virtual environment should, therefore, be akin to the real world in terms of connecting users' intended and actual movements.

5.2 Contextual Factors Affecting Virtual Presence in Immersive Metaverse-enabling Environments

We discovered several common contextual factors among several dimensions of virtual presence. For example, various studies showed user interactions with virtual characters to enhance all three dimensions of virtual presence (Kothgassner et al., 2018; Steed et al., 2018; Erickson-Davis et al., 2021; Voinea et al., 2022; Yuan & Gao, 2023). We do not view the findings with respect to fostering social presence, which relates directly to perceiving and interacting with others, as surprising. Further, with respect to spatial presence, one can attribute the findings to users' consuming attentional resources to interact with virtual characters. When users engage in interactions with virtual characters in a virtual environment, they may start paying less attention to specific imperfections that may exist in the environment. Additionally, user interactions with virtual characters can induce self-presence, which we may explain based on the fact that when virtual characters respond in ways that align with users' actions or emotions, users could feel their virtual selves as being acknowledged and interacted with in a realistic manner.

Studies also found an association between adopting a first-person perspective in virtual environments and both spatial presence and self-presence (Borrego et al., 2019; Dahlquist et al., 2010; Slater et al., 2010). Through evolution, the human perceptual system has been tuned to perceive the real world (Steuer, 1992). Appealing to the same perceptual mechanisms (and particularly a first-person perspective) aligns with how we perceive the world. This perspective can significantly enhance spatial presence as it allows users to see virtual environments directly through their eyes, which makes the experience more realistic. It also strengthens self-presence as the first-person perspective helps users better associate their virtual self with their real self (i.e., viewing their virtual body as an extension of their real body).

Interestingly, some contextual factors we identified do not only pertain to immersive metaverse-enabling environments. Engaging content (e.g., task complexity, meaningful content, narrative about the environment, among others) can foster spatial presence regardless of the immersion level. For instance, a study on retail mobile apps found that user engagement can stimulate the spatial presence experience (Ho et al., 2022). Such content's appeal lies in its ability to captivate and hold users' attention and, thereby, promote their psychological investment and sense of being "present" in the environment. Similarly, studies have emphasized virtual characters' human likeness and responsiveness as essential for eliciting self-presence in both immersive and non-immersive environments. Indeed, some studies on non-immersive environments have found that users prefer human-like, realistic virtual characters that they can connect with (Forlizzi et al., 2007; Ring et al., 2014). Further, research has found an association between the responsiveness of avatars that users control and self-presence (Jin & Park, 2009) likely due to the fact that the more closely virtual characters resemble and respond like humans, the more users can relate to them and perceive their own presence in the virtual environment. This dynamic holds true regardless of the environment's immersion level as it may tap into innate human tendencies to seek connection and responsiveness in social interactions (Forlizzi et al., 2007; Ring et al., 2014; Jin & Park, 2009).

5.3 Individual Factors Affecting Virtual Presence in Immersive Metaverse-enabling Environments

As with contextual factors, we found some common individual factors (absorptive capacities, negative emotions, and empathy) across multiple dimensions of presence. For example, absorptive tendencies can increase both spatial presence and social presence (Kober & Neuper, 2013; Erickson-Davis et al., 2021).
Users who exhibit high absorptive tendencies can engage more fully with a virtual environment’s spatial aspects and more deeply engage with virtual characters. Additionally, studies also found strong emotions (e.g., fear, paranoia, feeling threatened) to virtual stimuli to enhance all dimensions of virtual presence (Petkova & Ehrsson, 2008; Riches et al., 2019; Alsina-Jurnet et al., 2011; Mayer et al., 2022; Peperkorn et al., 2015; Price & Anderson, 2007; Regenbrecht et al., 1998; Riva et al., 2007). These findings indicate that strong reactions to virtual stimuli can make users more acutely aware of their surroundings and heighten their sensitivity to virtual cues present in the environment. Furthermore, studies found an association between empathy and both spatial presence and social presence (Ling et al., 2013; Wallach et al., 2010; Guadagno et al., 2011). One can view empathy (a form of emotional projection) as an emotional connection to a virtual place (and, thereby, enhance spatial presence) or virtual characters (and, thereby, enhance social presence).

Interestingly, some individual factors might be uniquely influential only in immersive environments. For example, no empirical evidence states that the independent viewpoint can affect one’s sense of social presence in environments without the immersion component. In immersive metaverse-enabling environments, the independent viewpoint can foster social presence through shared awareness and mutual non-verbal communication (Minghao & Jiro, 2019). The immersive environment facilitates a more realistic and compelling shared experience that might not be as achievable in non-immersive settings. Similarly, individuals with absorptive tendencies may experience greater social presence in immersive settings, while no such evidence exists for non-immersive environments. Further, detailed and engaging virtual worlds enrich individuals’ propensity to concentrate attention on specific elements, such as an avatar (Kober & Neuper, 2013). In contrast, non-immersive environments make users prone to non-sequitur disruptions (e.g., screen frames and desks comprise the physical space between users and technology) and, thereby, limit their ability to concentrate on specific aspects of virtual environments.

5.4 Design and Evaluation of Immersive Metaverse-enabling Environments

As Table 7 shows, we delineated various individual, contextual, and technological factors linked to different dimensions of virtual presence in immersive metaverse-enabling environments. We can leverage contextual and technological factors, which metaverse developers directly influence, to propose preliminary design principles for metaverse environments.

Design principles represent a recognized method for communicating emerging knowledge in design theory in design science research (DSR), a problem-solving approach that focuses on creating a novel artifact and associated knowledge (Gregor, 2006; Gregor & Hevner, 2013; Jones & Gregor, 2007). DSR contains three research cycles: the relevance cycle (which bridges the contextual information with the DSR activities), the rigor cycle (which connects the DSR activities with the knowledge base informing the research project), and the design cycle (which iterates between the activities of building and evaluating the artifact) (Hevner, 2007; Hevner et al., 2004). The knowledge base plays a pivotal role in the rigor cycle and includes methodologies and foundations (e.g., frameworks, design principles, theories, etc.) that can help shape the IT artifact evaluation. The knowledge base can be particularly useful for evaluating IT artifacts ex ante. To conduct ex ante evaluations, researchers estimate and evaluate the impact of an IT artifact on future situations and make decisions before actually constructing it (Stefanou, 2001; Venable et al., 2014). For instance, Stefanou et al. (2001) formulated a framework for evaluating ERP software ex ante to help managers comprehend the potential operational and strategic benefits in selecting and maintaining an ERP system. Similar to frameworks, design principles can also contribute to the knowledge base for DSR projects and provide a basis for the ex ante evaluations (Gregor, 2006; Gregor et al., 2020; Gregor & Hevner, 2013; Jones & Gregor, 2007; Bharosa et al., 2010).

To contribute to the knowledge base for future DSR projects focused on designing and evaluating the metaverse, we propose preliminary design principles for designing and evaluating immersive metaverse-enabling environments ex ante that can enhance users’ virtual presence experiences. We present the principles in Table 8.
### Table 8. Preliminary Design Principles for Inducing Virtual Presence

| Presence dimension                                                                 | Design principle (DP)                                                                 | Supporting citations                                                                 |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| To help users achieve spatial presence, immersive metaverse-enabling environments should... | Facilitate users’ physical movements (DP1)                                           | Clifton & Palmisano (2019), Cho et al. (2022)                                        |
|                                                                                   | Provide users with realistic visual feedback (DP2)                                   | Ling et al. (2012), Narciso et al. (2019)                                            |
|                                                                                   | Align users’ visual perspective with the real-world physical stance (DP3)            | Borrego et al. (2019), Dahlquist et al. (2010), Queiroz et al. (2023)                |
|                                                                                   | Consume users’ attentional resources through engaging and interactive elements (DP4)| Denzer et al. (2022), Dillon & Cai (2022), Gorini et al. (2010), Hoffman et al. (1998), Li et al. (2022), Ma & Kaber (2006), Oh et al. (2022), Slater et al. (1998), Steinicke et al. (2010), Kothgassner et al. (2018), Steed et al. (2018) |
|                                                                                   | Provide users with synchronized sensory cues (DP5)                                  | Baus & Bouchard (2016), Bessa et al. (2018), Chen et al. (2023), Ma & Kaber (2006), Mania & Robinson (2005), Slater et al. (1995) |
| To help users achieve social presence, immersive metaverse-enabling environments should... | Align users’ visual perspective with users’ movements (DP6)                         | Minghao & Jiro (2019)                                                               |
|                                                                                   | Provide users with opportunities for interactions with realistic virtual characters (DP7) | Erickson-Davis et al. (2021), Kothgassner et al. (2018), Voinea et al. (2022), Yuan & Gao (2023), Bailenson et al. (2005), Kwon et al. (2013), Guadagno et al. (2007) |
| To help users achieve self-presence, immersive metaverse-enabling environments should... | Align users’ visual perspective with the real-world physical stance (DP8)             | Borrego et al. (2019), Slater et al. (2010)                                         |
|                                                                                   | Provide users with human-like virtual bodies (DP9)                                  | Anvari et al. (2023), Petkova & Ehrsson (2008)                                     |
|                                                                                   | Be synchronized with and responsive to users’ physical movement (DP10)              | Petkova & Ehrsson (2008), Leonardis et al. (2014)                                  |
|                                                                                   | Contain responsive and user-like virtual characters (DP11)                          | Radiah et al. (2023), Suk & Laine (2023), Steed et al. (2018)                       |

Our design principles generally emphasize the importance of facilitating users’ physical movements, providing appropriate visual and other types of cues, and providing users with opportunities for interactions with virtual characters. To support spatial presence, immersive metaverse-enabling environments should be able to facilitate various aspects of user interaction with technology (from physical movements to sensory cues). In particular, designers can support DP1 (i.e., physical movements in the environment) by incorporating steering locomotion and hand-tracking functions as prior studies have evidenced (Clifton & Palmisano, 2019; Cho et al., 2022). DP2 and DP3 also emphasize the important role that visual elements play in facilitating spatial presence. The environment should provide users with realistic visual feedback (DP2), which one can deliver through a stereoscopic display as prior empirical evidence has shown (Ling et al., 2012; Narciso et al., 2019). Further, users’ visual perspective should align with the real-world physical stance (DP3). Designers can achieve this DP through a first-person perspective and a standing position display (Borrego et al., 2019; Dahlquist et al., 2010; Queiroz et al., 2023). In addition, immersive metaverse-enabling environments should provide users with various engaging and interactive elements to support spatial presence (DP4). These elements can include engaging content and interactive virtual characters (Denzer et al., 2022; Dillon & Cai, 2022; Gorini et al., 2010; Hoffman et al., 1998; Li et al., 2022; Ma & Kaber, 2006; Oh et al., 2022; Slater et al., 1998; Steinicke et al., 2010; Kothgassner et al., 2018; Steed et al., 2018). DP5 emphasizes the importance of synchronized sensory cues in the environment. Users should be exposed to synchronized visual, auditory, tactile, and olfactory cues (Baus & Bouchard, 2016; Bessa et al., 2018; Chen et al., 2023; Ma & Kaber, 2006; Mania & Robinson, 2005; Slater et al., 1995).

Our design principles on social presence focus primarily on users’ visual perspective and interactions with virtual characters. In particular, designers should ensure that immersive metaverse-enabling environments align with users’ movements in such environments (DP6). To support this alignment, designers can enable independent viewpoints in the environment (Minghao & Jiro, 2019). In addition, users should have
opportunities to interact with realistic virtual characters in the environment (DP7). Prior studies emphasize the importance of graphically realistic virtual characters that act naturally (Erickson-Davis et al., 2021; Kothgassner et al., 2018; Voinea et al., 2022; Yuan & Gao, 2023; Bailenson et al., 2005; Kwon et al., 2013; Guadagno et al., 2007).

The self-presence design principles underline the importance of user’s virtual body. Similar to our design principle on spatial presence, an immersive metaverse-enabling environment should align users’ visual perspective with the real-world physical stance, which designers can achieve through a first-person perspective (DP8) (Borrego et al., 2019; Slater et al., 2010). Additionally, the environment should provide users with an extension of their virtual bodies by imitating the human-likeness of the bodies (DP9) and being responsive to users’ movements (DP10) (Anvari et al., 2023; Petkova & Ehrsson, 2008; Leonardis et al., 2014). Finally, immersive metaverse-enabling environments should provide users with responsive virtual characters that resemble users (DP11) (Radiah et al., 2023; Suk & Laine, 2023; Steed et al., 2018).

While our design principles have their roots in existing empirical evidence, future DSR projects should evaluate their effectiveness when incorporated into immersive system design and their influence on users’ presence experience. Such evaluations would aid in further validating these design principles. In addition, future studies should also explore each principle in more detail and develop associated subprinciples. For example, DP7 states that immersive metaverse-enabling environments should have realistic virtual characters to help users achieve social presence. To operationalize this principle, researchers should identify specific elements of graphical realism for virtual characters and evaluate them for their impact on social presence. When integrated into actual systems and validated comprehensively, these principles can guide software developers’ decision-making processes before they construct immersive metaverse-enabling environments.

In addition to validating the proposed preliminary design principles, researchers should also examine other research areas in the future, which we discuss next.

5.5 Research Agenda

Table 9 summarizes research questions pertinent to virtual presence that future research should address. Though clearly not exhaustive, we provide the research questions based on reviewing the empirical literature in virtual presence within immersive metaverse-enabling environments. In particular, we encourage future research to focus on areas such as interactions among presence dimensions, antecedents of virtual presence, application scenarios, and metaverse technologies.

| Area                                      | Research questions                                                                 |
|-------------------------------------------|------------------------------------------------------------------------------------|
| Interactions among presence dimensions    | • How important are the identified subfactors to spatial, social, and self-presence in immersive metaverse-enabling environments?  
• What relationships do the identified subfactors for spatial, social, and self-presence in immersive metaverse-enabling environments have with one another?  
• What relationships do spatial, social, and self-presence in immersive metaverse-enabling environments have with one another? |
| Antecedents of virtual presence           | • Why does users’ exposure to pleasant smells not enhance spatial presence (compared to unpleasant smells) in immersive metaverse-enabling environments?  
• Why do users experience greater social presence during their interactions with avatars compared to their interactions with agents in immersive metaverse-enabling environments?  
• What role does the virtual context play in the relationship between user emotions and spatial presence in immersive metaverse-enabling environments?  
• What individual states and traits can lead to self-presence in immersive metaverse-enabling environments? |
| Application scenarios                    | • How do different application scenarios in immersive metaverse-enabling environments influence the experience of virtual presence?  
• Do the same antecedents of virtual presence have consistent effects across different immersive metaverse-enabling environments? |
5.5.1 Interactions Among Presence Dimensions

First, while all research that we reviewed examined various factors and subfactors that relate to one or more dimensions of virtual presence (per our literature-search parameters and review focus), we found little research that has examined multiple subfactors at the same time either in or across factor categories. As a result, researchers should, in addition to identifying omitted subfactors, examine multiple influences on virtual presence at a time with an eye towards understanding both their relative importance with regard to their influences on the dimensions of virtual presence as well as the relationships and possible interactions between the subfactors. In doing so, researchers could clarify both the weight of different subfactors and their overlap in influencing one or more dimensions of virtual presence (and possibly combinations in which these subfactors interact together to affect those influences).

5.5.2 Antecedents of Virtual Presence

Other research questions focus on resolving unusual or conflicting findings from prior studies and expanding limited research on antecedents associated with specific dimensions of virtual presence. For example, Baus and Bauchard (2017) examined spatial presence in a virtual kitchen environment and found that unpleasant smells heightened participants’ sense of spatial presence in the research, but pleasant smells did not. While it may seem reasonable that a smell associated with a particular environment may foster the sense of “being there” (e.g., spatial presence), it remains less evident why a specific type of smell (unpleasant), particularly one which would not be generally associated with the virtual environment under consideration (e.g., a virtual kitchen) would have a differential effect on spatial presence than another type (pleasant). Such an empirical finding requires either revisiting the research or additional theoretical development and conceptualization before it can be put to practical use.

Moreover, it remains unclear why specific contexts (e.g., relaxing vs. stressful environments) and emotions (e.g., positive vs. negative) can lead to conflicting findings in relation to spatial presence (Riva et al., 2007). Similarly, prior studies have found that user interactions with avatars can lead to greater social presence than user interactions with agents (Kothgassner et al., 2018; Guadagno et al. 2007). Yet it remains unclear what is unique about the avatar condition (vs. the agent condition). Finally, our review results show that limited research has studied self-presence. As Table 7 shows, we identified the feeling of threat as the only individual factor associated with self-presence (Petkova & Ehrsson, 2008). Future research should focus on additional individual factors (e.g., states and traits similar to those that research has explored in relation to spatial presence and self-presence) in relation to self-presence.

5.5.3 Application Scenarios

The scenario in which one applies immersive metaverse-enabling environments can result in differences in how users experience virtual presence. For example, the results from immersive metaverse-enabling environments for chess may not apply to immersive metaverse-enabling environments for shopping since users in the two scenarios have different goals. However, researchers have mostly conducted research in laboratory environments with artificial tasks. Future research should examine whether the same antecedents exert the same influence on virtual presence under different application scenarios. Additionally, future research should consider the contextual elements and user profiles associated with a given application scenario. For instance, research in immersive metaverse-enabling environments for shopping should invite real consumers to try the shopping experience and, thereby, take consumers’ goals and behavior into account.

In addition, despite the immersive environment’s potential to assist individuals with disabilities (Standen & Brown, 2005), little research has targeted this demographic. Disabled people may sense virtual presence differently. For instance, people with autism spectrum disorder may perceive certain visual or auditory stimuli in immersive environments as overwhelming or discomforting, which can affect their sense of presence.
Thus, we do not know how different factors (that prior studies have discovered) can affect the sense of presence for people with different disabilities. Researchers should conduct more research to explore how to improve how disabled users in general and with specific disabilities experience virtual presence.

5.5.4 Metaverse Technologies

Our review indicates that current research on immersive metaverse-enabling environments primarily relies on technologies such as HMDs to provide multi-sensory stimulation. However, researchers must conceptualize the metaverse not only based on existing technologies but also on its intended purposes (Xi & Hamari, 2021). With this broader view, future research should explore new emerging technologies to bridge the gap between user and technology and enhance users’ virtual presence in immersive metaverse-enabling environments.

5.6 Limitations

In our scoping literature review, we focused on papers published in peer-reviewed journals. We intentionally excluded conference papers due to potential concerns about their quality as some may not have undergone a rigorous peer-review process. However, we acknowledge that conference papers and posters can provide valuable insights and encourage future researchers to explore these sources by employing techniques to assess such submissions’ quality. Additionally, we conducted our literature search in May 2023. Consequently, our review does not include publications released after this date. Future studies should incorporate more recent publications to ensure the findings remain current and comprehensive.

6 Conclusion

The metaverse stands poised to revolutionize service ecosystems in numerous aspects of life with immersion and virtual presence being key to its transformative potential. In this study, we have consolidated a wealth of empirical research to identify critical technological, individual, and contextual factors that shape virtual presence. Additionally, we have developed design principles to help guide efforts to create and evaluate immersive metaverse-enabling environments.

As interest in the metaverse continues to surge, future research must expand on our findings. Investigating additional factors that influence virtual presence and deciphering unusual results from previous studies will help researchers more deeply understand these digital realms. This pursuit will not only advance academic knowledge but also practice as it will inform efforts to develop more intuitive and engaging metaverse systems that more closely align with human experience. In essence, our study lays the groundwork for future explorations that will further unveil the metaverse’s complexities, a domain where technological innovation meets human interaction in a constantly evolving digital landscape.
References

Alsina-Jurnet, I., Gutiérrez-Maldonado, J., & Rangel-Gómez, M. (2011). The role of presence in the level of anxiety experienced in clinical virtual environments. Computers in Human Behavior, 27(1), 504–512.

Altschuller, S., & Benbunan-Fich, R. (2013). The pursuit of trust in ad hoc virtual teams: How much electronic portrayal is too much? European Journal of Information Systems, 22(6), 619–636.

Animesh, A., Pinsonneault, A., Yang, S. B., & Oh, W. (2011). An odyssey into virtual worlds: Exploring the impacts of technological and spatial environments on intention to purchase virtual products. MIS Quarterly, 35(3), 789–810.

Anvari, T., Park, K., & Kim, G. (2023). Upper body pose estimation using deep learning for a virtual reality avatar. Applied Sciences, 13(4).

Arksey, H., & O’Malley, L. (2005). Scoping studies: Towards a methodological framework. International Journal of Social Research Methodology, 8(1), 19–32.

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium theory revisited: Mutual gaze and personal space in virtual environments. Presence: Teleoperators & Virtual Environments, 10(6), 583–598.

Bailenson, J. N., Swinth, K., Hoyt, C., Persky, S., Dimov, A., & Blascovich, J. (2005). The independent and interactive effects of embodied-agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in immersive virtual environments. Presence: Teleoperators & Virtual Environments, 14(4), 379–393.

Baus, O., & Bouchard, S. (2016). Exposure to an unpleasant odour increases the sense of presence in virtual reality. Virtual Reality, 21(2), 59–74.

Bessa, M., Melo, M., Augusto de Sousa, A., & Vasconcelos-Raposo, J. (2018). The effects of body position on reflexive motor acts and the sense of presence in virtual environments. Computers & Graphics, 71, 35–41.

Bharosa, N., Janssen, M., & Bouwman, H. (2010). Ex-ante evaluation of disaster information systems: A gaming-simulation approach. In Proceedings of the International Conference on Information Systems for Crisis Response and Management.

Biocca, F. (1997). The cyborg's dilemma: Progressive embodiment in virtual environments. Journal of Computer-Mediated Communication, 3(2).

Biocca, F., Harms, C., & Burgoon, J. K. (2003). Toward a more robust theory and measure of social presence: review and suggested criteria. Presence: Teleoperators and Virtual Environments, 12(5), 456-480.

Biocca, F., Harms, C., & Gregg, J. (2001). The networked minds measure of social presence: Pilot test of the factor structure and concurrent validity. In Proceedings of the 4th Annual International Workshop on Presence.

Borrego, A., Latorre, J., Alcañiz, M., & Llorens, R. (2019). Embodiment and presence in virtual reality after stroke. A comparative study with healthy subjects. Frontiers in Neurology, 10, 1-8.

Chen, H. J. (2023). Gather in the metaverse: Learning outcomes, virtual presence, and perceptions of high- and low-achieving pre-service teachers of English as a foreign language. Education and Information Technologies, 29, 8549-8577.

Chen, J. V., Ha, Q. A., & Vu, M. T. (2023). The influences of virtual reality shopping characteristics on consumers’ impulse buying behavior. International Journal of Human–Computer Interaction, 39(17), 3473–3491.

Cho, Y., Hong, S., Kim, M., & Kim, J. (2022). DAVE: Deep learning-based asymmetric virtual environment for immersive experiential metaverse content. Electronics, 11(16).

Clifton, J., & Palmisano, S. (2019). Effects of steering locomotion and teleporting on cybersickness and presence in HMD-based virtual reality. Virtual Reality, 24(3), 453–468.
Gromer, D., Reinke, M., Christner, I., & Pauli, P. (2019). Causal interactive links between presence and fear.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly, 37*(2), 337–355.

Gregor, S., & Seidel, S. (2020). Research perspectives: The anatomy of a design principle. *Journal of the Association for Information Systems, 21*(6), 1622-1652.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly, 37*(2), 337–355.

Gromer, D., Reineke, M., Christner, I., & Pauli, P. (2019). Causal interactive links between presence and fear in virtual reality height exposure. *Frontiers in Psychology, 10*, 1-11.
Guadagno, R., Swinth, K., & Blascovich, J. (2011). Social evaluations of embodied agents and avatars. *Computers in Human Behavior, 27*(6), 2380-3285.

Guadagno, R. E., Blascovich, J., Bailenson, J. N., & McCall, C. (2007). Virtual humans and persuasion: the effects of agency and behavioral realism. *Media Psychology, 10*(1), 1–22.

Harrison W. J., Thompson M. B., Sanderson P. M. (2010). Multisensory integration with a head-mounted display: Background visual motion and sound motion. *Human Factors, 52*(1), 78–91.

Hartmann, T., Wirth, W., Vorderer, P., Klimmt, C., Schramm, H., & Böcking, S. (2015). Spatial presence theory: State of the art and challenges ahead. In M. Lombard, F. Biocca, J. Freeman, W. Ijselsteijn, R. J. Schaevitz (Eds.), *Immersed in Media: Telepresence Theory, Measurement & Technology* (pp. 115–135). Springer.

Hevner, A. R. (2007). A three cycle view of design science research. *Scandinavian Journal of Information Systems, 19*(2), 1-7.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly, 28*(1), 75–105.

Ho, X. H., Nguyen, D. P., Cheng, J. M. S., & Le, A. N. H. (2022). Customer engagement in the context of retail mobile apps: A contingency model integrating spatial presence experience and its drivers. *Journal of Retailing and Consumer Services, 66*, 1-14.

Hoffman, H. G., Prothero, J., Wells, M. J., & Groen, J. (1998). Virtual chess: Meaning enhances users’ sense of presence in virtual environments. *International Journal of Human-Computer Interaction, 10*(3), 251–263.

Huang, C. L., Luo, Y. F., Yang, S. C., Lu, C. M., & Chen, A. S. (2020). Influence of students’ learning style, sense of presence, and cognitive load on learning outcomes in an immersive virtual reality learning environment. *Journal of Educational Computing Research, 58*(3), 596–615.

Jones, D., & Gregor, S. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems, 8*(5), 312-335.

Jin, S. A. A., & Park, N. (2009). Parasocial interaction with my avatar: Effects of interdependent self-construal and the mediating role of self-presence in an avatar-based console game, Wii. *CyberPsychology & Behavior, 12*(6), 723–727.

Kim, T., & Biocca, F. (1997). Telepresence via television: Two dimensions of telepresence may have different connections to memory and persuasion. *Journal of Computer-Mediated Communication, 3*(2).

Kober, S. E., & Neuper, C. (2013). Personality and presence in virtual reality: Does their relationship depend on the used presence measure? *International Journal of Human-Computer Interaction, 29*(1), 13–25.

Kothgassner, O. D., Goreis, A., Kafka, J. X., Hlavacs, H., Beutl, L., Kryspin-Exner, I., & Felnhofer, A. (2018). Agency and gender influence older adults’ presence-related experiences in an interactive virtual environment. *Cyberpsychology, Behavior, and Social Networking, 21*(5), 318–324.

Kwon, J. H., Powell, J., & Chalmers, A. (2013). How level of realism influences anxiety in virtual reality environments for a job interview. *International Journal of Human-Computer Studies, 71*(10), 978–987.

Labovitz, S. (1968). Criteria for selecting a significance level: a note on the sacredness of .05. *The American Sociologist, 3*(3), 220-222.

Lee, K. M. (2004). Presence, explicated. *Communication Theory, 14*(1), 27–50.

Lee, L. H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C., & Hui, P. (2021). All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda. arXiv. Retrieved from https://arxiv.org/abs/2110.05352

Leonardis, D., Frisoli, A., Barsotti, M., Carrozzino, M., & Bergamasco, M. (2014). Multisensory feedback can enhance embodiment within an enriched virtual walking scenario. *Presence, 23*(3), 253–266.
Lessiter, J., Freeman, J., Keogh, E., & Davidoff, J. (2001). A cross-media presence questionnaire: The ITC-sense of presence inventory. *Presence: Teleoperators & Virtual Environments, 10*(3), 282–297.

Li, H., Du, X., Ma, H., Wang, Z., Li, Y., & Wu, J. (2022). The effect of virtual-reality-based restorative environments on creativity. *International Journal of Environmental Research and Public Health, 19*(19), 1-38.

Ling, Y., Brinkman, W. P., Nefs, H. T., Qu, C., & Heynderickx, I. (2012). Effects of stereoscopic viewing on presence, anxiety, and cybersickness in a virtual reality environment for public speaking. *Presence: Teleoperators and Virtual Environments, 21*(3), 254–267.

Ling, Y., Nefs, H. T., Brinkman, W.-P., Qu, C., & Heynderickx, I. (2013). The relationship between individual characteristics and experienced presence. *Computers in Human Behavior, 29*(4), 1519–1530.

Lombard, M., Ditton, T. B., & Weinstein, L. (2009). Measuring presence: The temple presence inventory. In *Proceedings of the 12th Annual International Workshop on Presence*.

Longo, M. R., Schüßler, F., Kammers, M. P., Tsakiris, M., & Haggard, P. (2008). What is embodiment? A psychometric approach. *Cognition, 107*(3), 978–998.

Ma, R., & Kaber, D. B. (2006). Presence, workload and performance effects of synthetic environment design factors. *International Journal of Human-Computer Studies, 64*(6), 541–552.

McMahan, A. (2013). Immersion, engagement, and presence: A method for analyzing 3-D video games. In M. J. P. Wolf & B. Perron (Eds.), *The video game theory reader* (pp. 67–86). Routledge.

Makransky, G., & Mayer, R. E. (2022). Benefits of taking a virtual field trip in immersive virtual reality: Evidence for the immersion principle in multimedia learning. *Educational Psychology Review, 34*(3), 1771–1798.

Maneuvrier, A., Decker, L. M., Ceyte, H., Fleury, P., & Renaud, P. (2020). Presence promotes performance on a virtual spatial cognition task: Impact of human factors on virtual reality assessment. *Frontiers in Virtual Reality, 1*, 1-17.

Mania, K., & Robinson, A. (2005). An experimental exploration of the relationship between subjective impressions of illumination and physical fidelity. *Computer and Graphics, 29*(1), 49–56.

Mayer, G., Gronewold, N., Polte, K., Hummel, S., Barniske, J., Korbel, J., Zarnekow, R., & Schultz, J. (2022). Experiences of patients and therapists testing a virtual reality exposure app for symptoms of claustrophobia: mixed methods study. *JMIR Mental Health, 9*(12), 1-19.

Minghao, C., & Jiro, T. (2019). Go together: Providing nonverbal awareness cues to enhance co-located sensation in remote communication. *Human-centric Computing and Information Sciences, 9*(1), 1-25.

Murray, C. D., Fox, J., & Pettifer, S. (2007). Absorption, dissociation, locus of control and presence in virtual reality. *Computers in Human Behavior, 23*(3), 1347–1354.

Mystakidis, S. (2022). Metaverse. *Encyclopedia, 2*(1), 486–497.

Nah, F. F. H., Eschenbrenner, B., & DeWester, D. (2011). Enhancing brand equity through flow and telepresence: A comparison of 2D and 3D virtual worlds. *MIS Quarterly, 35*(3), 731–747.

Narciso, D., Bessa, M., Melo, M., Coelho, A., & Vasconcelos-Raposo, J. (2019). Immersive 360 video user experience: impact of different variables in the sense of presence and cybersickness. *Universal Access in the Information Society, 18*(1), 77–87.

Nash, E. B., Edwards, G. W., Thompson, J. A., & Barfield, W. (2000). A review of presence and performance in virtual environments. *International Journal of Human-Computer Interaction, 12*(1), 1–41.

Ng, D. T. K. (2022). What is the metaverse? Definitions, technologies and the community of inquiry. *Australasian Journal of Educational Technology, 38*(4), 190-205.

Nilsson, N.C., Nordahl, R., & Serafin, S. (2016). Immersion revisited: A review of existing definitions of immersion and their relation to different theories of presence. *Human Technology, 12*(2), 108–134.

Oh, C. S., Bailenson, J. N., & Welch, G. F. (2018). A systematic review of social presence: Definition, antecedents, and implications. *Frontiers in Robotics and AI, 5*, 1-35.
Oh, H. J., Kim, J., Chang, J. J., Park, N., & Lee, S. (2023). Social benefits of living in the metaverse: The relationships among social presence, supportive interaction, social self-efficacy, and feelings of loneliness. *Computers in Human Behavior*, 139, 1-11.

Oh, J., Kim, D. H., & Kim, D. (2022). Exploring experiential patterns depending on time lapses in virtual reality spectatorship (VRS): The role of interruption in reducing satiation. *Sustainability*, 14(24), 1-14.

Park, S. M., & Kim, Y. G. (2022). A metaverse: Taxonomy, components, applications, and open challenges. *IEEE Access*, 10, 4209–4251.

Peperkorn, H. M., Diemer, J., & Mühlberger, A. (2015). Temporal dynamics in the relation between presence and fear in virtual reality. *Computers in Human Behavior*, 48, 542–547.

Peters, M. D. J., Godfrey, C. M., McInerney, K. H., Parker, D., & Baldini, S. C. (2017). Scoping reviews. In E. Aromataris & Z. Munn (Eds.), *Joanna Briggs Institute reviewer’s manual* (pp. 1–24). The Joana Briggs Institute.

Petkova, V. I., & Ehrsson, H. H. (2008). If I were you: Perceptual illusion of body swapping. *PloS One*, 3(12).

Polhemus, L., Shih, L. F., & Swan, K. (2001). Virtual interactivity: The representation of social presence in an online discussion. In *Proceedings of the Annual International Meeting of the American Educational Research Association*.

Price, M., & Anderson, P. (2007). The role of presence in virtual reality exposure therapy. *Journal of Anxiety Disorders*, 21(5), 742–751.

Qiu, L., & Benbasat, I. (2009). Evaluating anthropomorphic product recommendation agents: A social relationship perspective to designing information systems. *Journal of Management Information Systems*, 25(4), 145–182.

Queiroz, A. C., Fauville, G., Abeles, A. T., Levett, A., & Bailenson, J. N. (2023). The efficacy of virtual reality in climate change education increases with amount of body movement and message specificity. *Sustainability*, 15(7), 1-24.

Radiah, R., Roth, D., Alt, F., & Abdelrahman, Y. (2023). The influence of avatar personalization on emotions in VR. *Multimodal Technologies and Interaction*, 7(4), 1-16.

Ratan, R. (2013). Self-presence, explicated: Body, emotion, and identity extension into the virtual self. In R. Luppicini (Ed.), *Handbook of research on technoself: Identity in a technological society* (pp. 322–336). IGI Global.

Ratan, R. A., & Hasler, B. (2009). Self-presence standardized: Introducing the self-presence questionnaire (SPQ). In *Proceedings of the 12th Annual International Workshop on Presence*.

Ratan, R., & Hasler, B. S. (2010). Exploring self-presence in collaborative virtual teams. *PsychNology Journal*, 8(1), 11-31.

Regenbrecht, H. T., Schubert, T. W., & Friedmann, F. (1998). Measuring the sense of presence and its relations to fear of heights in virtual environments. *International Journal of Human–Computer Interaction*, 10(3), 233-249.

Riches, S., Elghany, S., Garety, P., Rus-Calafell, M., & Valmaggia, L. (2019). Factors affecting sense of presence in a virtual reality social environment: A qualitative study. *Cyberpsychology, Behavior and Social Networking*, 22(4), 288-292.

Ring, L., Utami, D., & Bickmore, T. (2014). The right agent for the job? The effects of agent visual appearance on task domain. In *Proceedings of the 14th International Conference on Intelligent Virtual Agents*.

Riva, G. (2008). Enacting interactivity: The role of presence. In F. Morganti, A. Carassa, & G. Riva (Eds.), *Enacting intersubjectivity* (pp. 97–114). IOS Press.

Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., Gaggioli, A., Botella, C., & Alcañiz, M. (2007). Affective interactions using virtual reality: the link between presence and emotions. *Cyberpsychology & Behavior*, 10(1), 45-56.
Riva, G., Waterworth, J. A., & Waterworth, E. L. (2004). The layers of presence: A bio-cultural approach to understanding presence in natural and mediated environments. *CyberPsychology & Behavior, 7*(4), 402–416.

Rodriguez-Ardura, I., & Meseguer-Artola, A. (2018). Immersive experiences in online higher education: Virtual presence and flow. In A. Visvizi, M. D. Lytras, & L. Daniela (Eds.), *The future of innovation and technology in education: Policies and practices for teaching and learning excellence* (pp. 187–202). Emerald.

Roth, D., & Latoschik, M. E. (2020). Construction of the virtual embodiment questionnaire (VEQ). *IEEE Transactions on Visualization and Computer Graphics, 26*(12), 3546–3556.

Sas, C., & O’Hare, G. M. (2003). Presence equation: An investigation into cognitive factors underlying presence. *Presence, 12*(5), 523–537.

Saunders, C., Rutkowski, A. F., Genuchten, M. v., Vogel, D., & Orrego, J. M. (2011). Virtual presence in immersive virtual environments. *Presence: Teleoperators and Virtual Environments, 20*(4), 449.

Schubert, T. W. (2009). A new conception of spatial presence: Once again, with feeling. *Communication Theory, 19*(2), 161–187.

Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. *Presence: Teleoperators and Virtual Environments, 10*(3), 266–281.

Schuermie, M. J., Van Der Straaten, P., Krijn, M., & Van Der Mast, C. A. (2001). Research on presence in virtual reality: A survey. *Cyberpsychology & Behavior, 4*(2), 183–201.

Schultze, U. (2010). Embodiment and presence in virtual worlds: A review. *Journal of Information Technology, 25*(4), 434–449.

Schultze, U., & Brooks, J. A. M. (2019). An interactional view of social presence: Making the virtual other “real”. *Information Systems Journal, 29*(3), 707–737.

Short, J., Williams, E., & Christie, B. (1976). *The social psychology of telecommunications*. Wiley.

Sia, C. L., Tan, B. C., & Wei, K. K. (2002). Group polarization and computer-mediated communication: Effects of communication cues, social presence, and anonymity. *Information Systems Research, 13*(1), 70–90.

Slater, M. (2003). A note on presence terminology. *Presence Connect, 3*(3), 1–5.

Slater, M., Spanlang, B., Sanchez-Vives, M. V., & Blanke, O. (2010). First person experience of body transfer in virtual reality. *PLoS One, 5*(5), 1–9.

Slater, M., Steed, A., McCarthy, J., & Maringelli, F. (1998). The influence of body movement on subjective presence in virtual environments. *Human Factors, 10*(3), 469–477.

Slater, M., Usoh, M., & Chrysanthou, Y. (1995). The influence of dynamic shadows on presence in immersive virtual environments. In *Proceedings of Virtual Environments*.

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and Virtual Environments, 6*(6), 603–616.

Srivastava, S. C., & Chandra, S. (2018). Social presence in virtual world collaboration: An uncertainty reduction perspective using a mixed methods approach. *MIS Quarterly, 42*(3), 779–803.

Standen, P. J., & Brown, D. J. (2005). Virtual reality in the rehabilitation of people with intellectual disabilities: review. *Cyberpsychology & Behavior, 8*(3), 272–288.

Steed, A., Pan, Y., Watson, Z., & Slater, M. (2018). “We wait”—the impact of character responsiveness and self embodiment on presence and interest in an immersive news experience. *Frontiers in Robotics and AI, 5*, 1–14.

Stefanou, C. J. (2001). A framework for the ex-ante evaluation of ERP software. *European Journal of Information Systems, 10*(4), 204–215.
Steinicke, F., Bruder, G., Hinrichs, K., & Steed, A. (2010). Gradual transitions and their effects on presence and distance estimation. *Computers & Graphics, 34*(1), 26–33.

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of Communication, 42*(4), 73–93.

Subramaniam, N., Nandhakumar, J., & Baptista, J. (2013). Exploring social network interactions in enterprise systems: the role of virtual co-presence. *Information Systems Journal, 23*(6), 475–499.

Suk, H., & Laine, T. H. (2023). Influence of avatar facial appearance on users’ perceived embodiment and presence in immersive virtual reality. *Electronics, 12*(3), 1–21.

Swinth, K. R., & Blascovich, J. (2001). Conformity to group norms in an immersive virtual environment. In *Proceedings of the Annual Meeting of the American Psychological Society*.

Tamborini, R., & Skalski, P. (2006). The role of presence in the experience of electronic games. In P. V. J. Bryant (Ed.), *Playing video games: Motives, responses, and consequences* (pp. 225–240). Lawrence Erlbaum Associates.

Tellegen, A., & Atkinson, G. (1974). Openness to absorbing and self-altering experiences (“absorption”), a trait related to hypnotic susceptibility. *Journal of Abnormal Psychology, 83*(3), 268–277.

Triberti, S., Brivio, E., & Galimberti, C. (2018). On social presence: Theories, methodologies, and guidelines for the innovative contexts of computer-mediated learning. In M. Marmon (Ed.), *Enhancing social presence in online learning environments* (pp. 20–41). IGI Global.

Tricco, A. C., Antony, J., Zarin, W., Strifler, L., Ghassemi, M., Ivory, J., Perrier, L., Hutton, B., Moher, D., & Straus, S. E. (2015). A scoping review of rapid review methods. *BMC Medicine, 13*(1), 1–15.

Usoh, M., Catena, E., Arman, S., & Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments, 9*(5), 497–503.

Venable, J., Pries-Heje, J., & Baskerville, R. (2014). FEDS: A framework for evaluation in design science research. *European Journal of Information Systems, 25*(1), 77–89.

Voinea, G. D., Girbacia, F., Postelnicu, C. C., Duguleana, M., Antonya, C., Soica, A., & Stănescu, R.-C. (2022). Study of social presence while interacting in metaverse with an augmented avatar during autonomous driving. *Applied Sciences, 12*(22), 1–12.

Vorderer, P., Wirth, W., Gouveia, F. R., Biocca, F., Saari, T., Jäncke, F., Böcking, S., Schramm, H., Gysbers, A., Hartmann, T., Klimmt, C., Laarni, J., Ravaja, N., Sacau, A., Baumgartner, T., & Jäncke, P. (2004). *MEC spatial presence questionnaire (MEC-SPQ): Short documentation and instructions for application*. Retrieved from http://www.ijk.hmt-hannover.de/presenc

Wang, H., Ning, H., Lin, Y., Wang, W., Dhelim, S., Farha, F., Ding, J., & Daneshmand, M. (2023). A survey on the metaverse: the state-of-the-art, technologies, applications, and challenges. *IEEE Internet of Things Journal, 10*(16), 14671–14688.

Wallach, H. S., Safir, M. P., & Samana, R. (2010). Personality variables and presence. *Virtual Reality, 14*(1), 3–13.

Wei, W., Ruoxi, Q., & Lu, Z. (2019). Effects of virtual reality on theme park visitors’ experience and behaviors: a presence perspective. *Tourism Management, 71*, 282–293.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence, 7*(3), 225–240.

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., Gouveia, F. R., Biocca, F., Sacau, A., Jäncke, L., Baumgartner, T., & Jäncke, P. (2007). A process model of the formation of spatial presence experiences. *Media Psychology, 9*(3), 493–525.

Xi, N., & Hamari, J. (2021). Shopping in virtual reality: a literature review and future agenda. *Journal of Business Research, 134*, 37–58.

Xu, M., Ng, W. C., Lim, W. Y. B., Kang, J., Xiong, Z., Niyato, D., Yang, Q., Shen, X., & Miao, C. (2022). A full dive into realizing the edge-enabled metaverse: visions, enabling technologies, and challenges. *IEEE Communications Surveys & Tutorials, 25*(1), 656–700.
Yoo, Y., & Alavi, M. (2001). Media and group cohesion: Relative influences on social presence, task participation, and group consensus. *MIS Quarterly, 25*(3), 371–390.

Yuan, Q., & Gao, Q. (2023). Being there, and being together: Avatar appearance and peer interaction in VR classrooms for video-based learning. *International Journal of Human-Computer Interaction, 40*(13), 3313-3333.

Zhang, D., Lowry, P. B., Zhou, L., & Fu, X. (2007). The impact of individualism—collectivism, social presence, and group diversity on group decision making under majority influence. *Journal of Management Information Systems, 23*(4), 53–80.
Appendix A: Descriptive Information of the Reviewed Papers

Table A1. Publication Year Distribution (Sorted Chronologically)

| Year | Count |
|------|-------|
| 1995 | 1     |
| 1998 | 3     |
| 2005 | 2     |
| 2006 | 1     |
| 2007 | 4     |
| 2008 | 1     |
| 2010 | 5     |
| 2011 | 2     |
| 2012 | 1     |
| 2013 | 3     |
| 2014 | 1     |
| 2015 | 1     |
| 2016 | 2     |
| 2018 | 3     |
| 2019 | 7     |
| 2020 | 2     |
| 2021 | 1     |
| 2022 | 7     |
| 2023 | 6     |

Table A2. Journal Distribution (Sorted Alphabetically)

| Journal                                      | Count |
|----------------------------------------------|-------|
| Applied Sciences                             | 2     |
| Computers & Graphics                         | 3     |
| Computers in Human Behavior                  | 5     |
| Consciousness and Cognition                  | 1     |
| Cyberpsychology & Behavior                   | 1     |
| Cyberpsychology, Behavior and Social Networking | 3     |
| Electronics                                  | 2     |
| Frontiers in Neurology                       | 1     |
| Frontiers in Psychology                      | 1     |
| Frontiers in Robotics and AI                 | 1     |
| Frontiers in Virtual Reality                 | 1     |
| Human Factors                                | 1     |
| Human-centric Computing and Information Sciences | 1     |
| International Journal of Environmental Research and Public Health | 1     |
| International Journal of Human-Computer Interaction | 5     |
| International Journal of Human-Computer Studies | 2     |
| JMIR Mental Health                           | 1     |
| Journal of Anxiety Disorders                 | 1     |
### Table A2. Journal Distribution (Sorted Alphabetically)

| Journal Name                                           | Count |
|--------------------------------------------------------|-------|
| Journal of Educational Computing Research              | 1     |
| Media Psychology                                       | 1     |
| Multidisciplinary Scientific Journal                   | 1     |
| Multimodal Technologies and Interaction                 | 1     |
| PLOS One                                               | 2     |
| Presence: Teleoperators & Virtual Environment           | 3     |
| Religion, Brain, and Behavior                          | 1     |
| Studies in health technology and informatics            | 1     |
| Sustainability                                         | 2     |
| Tourism Management                                     | 1     |
| Universal Access in the Information Society            | 1     |
| Virtual Environments                                   | 1     |
| Virtual Reality                                        | 4     |
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