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Being there but where? Sense of presence theory for virtual reality applications

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The sense of presence—the psychological experience of "being there"—has emerged as a critical phenomenon in Virtual Reality (VR) research. While traditional approaches have predominantly focused on technological features as primary drivers of presence, this paper argues that such a view is fundamentally incomplete. We contend that presence is primarily a psychological phenomenon shaped by three critical dimensions that extend beyond mere technological sophistication: (1) the impact of content and narrative structure in virtual environments, (2) the influence of users' individual characteristics and sociocultural contexts, and (3) the relationship between presence and users' intentional structures. Through a synthesis of current evidence, we demonstrate that these psychological and social factors often outweigh technical considerations in determining the quality of presence experiences. As immersive technologies become increasingly prevalent in shared environments and sensitive contexts such as education and healthcare, this more sophisticated understanding of presence becomes crucial for designing effective virtual experiences. We argue that future VR development should shift from a predominantly technology-centered approach to one that carefully considers these psychological and social dimensions to achieve intended outcomes while accounting for individual and cultural variability.

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Introduction

Virtual Reality (VR), along with its numerous applications, is a technology studied since the late Eighties, taking into account that the first experiments can be found in the Fifties and Sixties, by the hands of pioneers such as Ivan Sutherland and Morton Heilig (Bown, White, and Boopalan 2017).

Since the last years of the previous century, VR has been widely explored in many fields, the most delicate being healthcare: the research has shown that VR is an effective resource for pain management and psychotherapy, especially in terms of patients' exposure to pathogenic stimuli (e.g., in phobias and post-traumatic stress disorder) in order to promote effective emotion regulation strategies (Riva 2022; Meyerbroker 2021; Colombo et al. 2021).

Already pioneer studies on VR highlighted that the technology is particularly effective given that it could obtain a realistic "illusion" of an alternative reality (Slater et al. 2022), so that users will react emotionally and behaviorally to simulations as if they were part of the real world. However, the research has soon discovered that such an illusion is not a mere consequence of using VR per se: it could vary between different technologies (De Paolis and De Luca 2022; Barranco Merino et al. 2023), different simulations (Schroder et al. 2024), and even between participants based on individual characteristics such as sex, age, personality, previous knowledge and expectations (Nicovich, Boller, and Cornwell 2005; Weech, Kenny and Barnett-Cowan 2019; Sacau, Laarni, and Hartmann 2008; Ciarmoli et al. 2024). These discoveries are associated with the concept of *sense of presence*, namely the psychological counterpart of technological immersion, defined as the sensation of being within a place or situation. Before deepening the theoretical achievements and evidence related to sense of presence, it is important to address recent changes in the global scenario. In the last decades, many things changed in the VR field: while until approximately 2000 VR was a technology one could try at specific events or within specialized laboratories, today it became a wide commercial product. According to Statista, in 2022 there were 171 millions of VR users worldwide. In 2024 14.3 million of VR headsets were sold, almost tripling those sold in 2019[1].

This growth is connected to important companies such as Meta (formerly Facebook) that are investing in immersive social experiences starting from the Metaverse, a collection of virtual worlds that could be explored by multiple users at a time. Taking into consideration the important investments in VR, it is paramount to deepen the factors that affect its effectiveness for multiple aims.

Indeed, presence is not only a curious phenomenon of interest for cognitive scientists and technology experts, but a process that has been demonstrated to affect VR effectiveness. For example, VR-based analgesia is influenced by sense of presence (Triberti, Repetto and Riva 2014), and so are many VR applications ranging from healthcare to marketing and entertainment (McCreery et al. 2013; Servotte et al. 2020; Coelho et al., 2006; Hwuang, Chang and Chien 2022). Based on recent publications, it appears that limited conceptions of sense of presence are still common in the literature (Korżel and Łupkowski 2023; Rudi 2021; Rojas Ferrer et al. (2020)). In this contribution we summarize important aspects emerging from the research on sense of presence and try to adapt them to novel contexts and issues.

Do *machines* generate the sense of presence?

As hinted at in the introduction, a first misconception refers to sense of presence as the sub-product of technological features of VR. In other words, people may believe that presence is an automatic consequence of the mere fact of using VR (e.g., an "on-off" sensation) or, in a slightly more complex conception, that VR will generate more or less presence depending on its technological sophistication. In other words, feeling more or less sense of presence would be a byproduct of VR simulating a high number of perceptual stimuli, or its graphical vividness, or the complexity of the interactive devices involved.

While these factors appear to play a role in the generation and modulation of sense of presence (Azofeifa et al. 2022), there seems to be more to the story. The research has demonstrated that the *content* of a virtual environment, such as for example a narrative and the identification of clear goals beyond mere exploration, strongly affect the sensation of "being there" (Gorini et al. 2011; Riches et al. 2019). Consistently, both as a result of research and anecdotally, video game players report strong sense of presence for virtual environments that have been experienced with limited devices (e.g., desktop computer, or even mobile), due to compelling storylines and engaging gameplay. A classical study by Villani et al. (2012) challenged the traditional view that presence in mediated experiences can at best equal, but not exceed, presence in reality. The study compared presence in a VR job interview simulation versus a real-world simulation without contextual cues. Results showed higher self-reported presence and anxiety in the VR condition, suggesting that the social and cultural cues in VR provided greater meaning to the experience. This highlights that sense of presence is ultimately a feature of personal experience and is influenced by the coherence between environmental features and user expectations/meaning attribution (Mantovani and Riva 1999; Pianzola, Riva, Kukkonen and Mantovani 2021, 2022). Such evidence is still relatively under-explored in VR research compared with studies on technical aspects or mere media comparison (e.g., VR vs. desktop): for this reason, future studies in the field should give more attention to "content" features such as narrative and emotions to investigate further the factors that allow simulations to promote meaningful change in their users. This could be done, for example, by exposing experimental participants to the same virtual environment but with different narratives that attach different meanings to objects and events happening in the scenarios.

Is presence a result of using virtual reality?

This question is slightly different from the previous one, but it pertains to a broader philosophy of the concept. The possible responses could be grouped into two main approaches, namely media presence and inner presence theories (Coelho et al. 2006; Mantovani and Riva 1999; Riva, Waterworth, Waterworth and Mantovani 2011; Waterworth, Mantovani and Riva 2012; Triberti and Riva 2016). According to the first approach, the sense of presence would be the result of the experience with a given medium. By simulating physical reality to some degree of realism, technology could "trigger" our brain to generate some never-seen-before sensation (or illusion) to actually be in another place. However, as observed by inner presence theorists (Coelho et al. 2006), media presence theories ultimately fail when trying to explain "what is sense of presence *for*" from an evolutionary point of view. According to inner presence theories, the sense of presence should be conceptualized as a fundamental function of human cognition, independent of the experience of technologies but that became apparent thanks to the research on immersive technologies, especially VR (Riva, Mantovani, Waterworth and Waterworth 2015). Sense of presence is a faculty of our mind, mainly devoted to identifying the environment we are in, so that we are able to enact our own intentions and define our activity in the world (Riva 2009; Riva et al. 2014; Pianzola et al. 2021, 2022). On the one hand, this fundamental function could be "tricked" by immersive technologies as they can reproduce an external

environment in terms of perceptual, agentic and meaningful features. In fact, VR shares with the brain the same basic mechanism: embodied simulations (Riva, Wiederhold and Mantovani 2019). An increasingly popular neuroscience theory—predictive coding— proposes that our brain continuously generates and updates an internal representation or model of our body and its surroundings. This model serves two primary functions: it anticipates the sensory information we're likely to encounter, and it works to reduce discrepancies between these predictions and actual sensory input. In essence, the brain is constantly trying to minimize "surprises" or prediction errors by refining its internal simulation based on incoming sensory data. VR technology operates on principles similar to the brain's predictive mechanisms. It employs sophisticated computer systems to generate an interactive, artificial environment that users can engage with as though it were real. The VR system anticipates the sensory feedback a user would expect based on their actions and presents a corresponding visual scene that mimics real-world experiences. This is achieved through a combination of hardware and software: motion-tracking devices monitor the user's movements, while the VR software continuously updates the visual display to reflect how these movements would alter the user's perspective in the virtual environment. This real-time adjustment creates a seamless and immersive experience, making the virtual world feel responsive and authentic to the user's actions. On the other hand, thanks to the fact that such embodied simulations could be promoted within simulated environments, humans are able to undergo pregnant experiences within them and transfer abilities and knowledge to the challenges of the real world. The more closely the VR model mimics the brain's model, the stronger the sense of presence a user feels in the virtual world. In essence, VR has the capacity to "trick" these predictive coding processes in the brain. It can create a compelling illusion of presence within a virtual body and digital environment that feels authentic to the user. This illusion is so powerful that it can override our normal sense of embodiment, making us feel as though we genuinely inhabit the virtual space and body.

Future research should explore the parallels between virtual reality experiences and the brain's inherent predictive mechanisms through two primary approaches. First, in-depth qualitative research could investigate how individuals, particularly those with limited VR exposure, experience virtual environments. Such studies would examine fundamental questions: How does VR perception compare to real-world experiences? What factors influence the varying sensations of presence or "being there"? This approach would prioritize rich, unconstrained subjective descriptions over traditional questionnaire-based assessments, potentially revealing nuanced insights about immersive experiences.

Second, advances in VR technology present opportunities for innovative neuropsychological research. As VR headsets become increasingly compatible with neuropsychological measurement tools, researchers could adapt predictive coding methodologies (such as those examining differential brain responses to predictable versus unpredictable stimuli; De-Wit et al., (2010)) to VR contexts. This integration would enable direct comparative studies of how the brain processes virtual versus real-world environments, advancing our understanding of immersive technology's impact on human perception and cognition.

Is presence an engineering or psychological issue?

Based on the reflections above, *immersion* is mostly an engineering/technological issue: immersion could be defined based on the number of technological devices and/or the level of graphical vividness or, in other words, in terms of the degree to which more or less devices are involved in order to give users an extensive illusion of alternative reality.

Sense of presence, instead, is a psychological issue: first, at the phenomenological level presence manifests "within the mind" of an individual, in the sense that it should be necessarily understood as a sensation. So, it depends on how people perceive and interpret a situation (real or virtual), and it could develop into a complex mental representation informing one about location, goals, opportunities and activities. By grounding this vision in a 4E conception of the mind (Pianzola et al. 2021) - embodied, embedded in the social context, extended into the environment, and enactive – it is possible to suggest that subjects experience *presence* when they are able to correctly and intuitively enact (i.e., without the involvement of reasoning) their implicit (predictive processing) and explicit (intentions) embodied predictions (Riva 2018; Pianzola et al. 2022).

To recognize the psychological nature of sense of presence, individual factors are also relevant. An important number of studies demonstrated that factors such as sex, age, personality, previous knowledge and expectations influence the sense of presence in virtual environments (Alsina-Jurnet, Gutiérrez-Maldonado (2010); Wallach, Safir and Samana 2010; Galloso, et al. 2016; Phillips, et al. 2012), highlighting that people may feel more or less present in the same environment depending on individual predispositions and predictions, independently of the technological characteristics of the simulation. This points towards the importance of *personalization* of VR contents, as in some recent approaches (Pizzoli et al. 2019; Pardini et al. 2022). By rejecting a "one-size-fits-all" approach, future VR interventions may harness both user centered research methods and generative Artificial Intelligence to develop VR that adapts to users' characteristics and needs, so that the experience could turn out more immersive and meaningful.

Are socio-cultural factors involved in the onset or maintenance of sense of presence?

An interesting question is whether the overall experience of presence within a virtual environment is influenced by social-cultural factors. Human mental representation is developed by individuals to inform themselves about goals, benefits and opportunities or risks that surround them in the environment. That's the way individuals feel to be present to themselves, living in a specific environment, living in a situation. We feel that we are part of it, completely and consciously aware. Mental representation depends on several factors, not strictly individual. There are also social and cultural factors that influence cognition and information processing, starting from the perspective of the self (Kitayama and Salvador 2024; Riva et al. 2004).

Culture is defined as patterns of representations (e.g. lay theories, scripts and worldviews) embodied in institutions, practices, artifacts and public narratives that exist simultaneously in people and contexts (Adams, Markus (2004)). People managing situations in a multicultural environment often have to switch from different cultural schemes depending on their immediate context (Hong et al. 2000). Socio-cultural engagement is an active and constant process of human life (Kitayama, Cohen 2010).

Regarding the VR environment, it is interesting to briefly highlight how socio-cultural influences are investigated with respect to the sense of presence. Nowadays, several VR applications are used in the field of cultural heritage (e.g. museum exhibitions) thus a definition of *cultural presence* has been developed with respect to the environments where ancient places have been reproduced. Shehade, Stylianou-Lambert (2024) with reference to cultural presence in VR environments, consider it not a merely reproduction of the place but also "*the transmission of*

the social or other values of the objects in question, and the interaction of the user for active engagement".

Another way to explore cultural influence in the sense of presence in VR is cross-cultural studies like Shadiev et al. (2021). They started from the assumption that several cross-cultural learning projects based on VR environments, that were developed for students coming from different cultures, were not useful for cross-cultural learning. They designed a cross-cultural activity for Chinese and Uzbek citizens in VR based on a 360-degree video. The results demonstrated that a sense of presence among the students, their perceived self-control and knowledge of each other's culture improved.

It is well known in psychological literature that people belonging to different cultural backgrounds process perceptual stimuli differently (Nisbett et al., (2001); Norenzayan et al., (2002); Senzaki et al., (2014)). Western and eastern people are characterized by a more analytic/holistic cognitive style respectively. Consistently, the research developed by Šašinková et al., (2023) demonstrated that cultural background has an influence on the human perception of complex visual stimuli even in a VR environment. The results of this study show that five groups native to different countries (spanning across Europe, Africa, Asia) show some difference in processing complex visual stimuli in VR. While the sense of presence was not measured in this study, these results highlight the importance to take into consideration the different mindsets that may characterize users in the perception of VR, possibly influencing their perception of "being there" as well.

Building on this, we can propose a cultural perspective that sees presence as socially constructed and mediated by cultural tools and frameworks (Mantovani and Riva 1999; Triberti and Riva 2016). In this view all experience is mediated, situated in social contexts, and inherently ambiguous. Culture provides shared references to manage this ambiguity.

For this reason, presence requires both a cultural framework and the ability to negotiate actions and meanings socially. This allows for a more nuanced understanding of presence across physical, telepresent, and virtual environments. It emphasizes social interaction and the co-construction of reality over simply mimicking physical presence.

This cultural perspective, by embracing social reality and everyday life, offers a more productive foundation for developing and evaluating VR systems. It suggests presence can be measured by how well social actors can perform tasks individually (presence) or collaboratively in ambiguous, negotiated contexts. This discussion leads to the related concept of social presence (SP) - the sensation of being in the company of others (Triberti, Brivio and Galimberti 2018; Pianzola et al. 2021). Historically, SP theories emphasized "media richness" or technological sophistication in mediated communication, suggesting that increasing the quantity or precision of communication tools would automatically enhance SP. However, contemporary research challenges this assumption: SP can be heightened by the pre-existing depth of social relationships regardless of the communication medium (Gunawardena and Zittle 1997), or can emerge strongly from subtle but meaningful cues that allow users to interpret others' intentions and actions (Biocca, Harms and Burgoon 2003; Riva et al. 2015). For instance, both in physical and virtual environments, a strong sense of SP may arise simply from discovering footprints on the ground (Triberti, Brivio and Galimberti 2018).

SP likely influences presence fundamentally: engaging with others, from detecting their traces or messages to complex interaction and dialogue, is crucial for meaning-making and the development of shared knowledge and culture. Notably, these "others" need not to be human but can include intentional artificial entities, such as non-player characters in video games. Understanding how the presence of others and the diverse relationships possible in shared VR environments affect the technology's effectiveness remains a critical area for future research.

What does *really* matter in VR to obtain a sense of presence?

Ultimately, the sense of presence within immersive technologies is important for user experience, human-computer interaction and all those disciplines that aim at improving safety, usability and functionality of technologies. Triberti and Riva (2016) proposed a model for technology evaluation that is strictly connected to the concept of presence. Taking into consideration individual and socio-cultural aspects, the model focuses on the role of intentions in any human-technology interaction. Classical usability has focused mostly on the role of interface and devices, aiming at improving their utilizability in terms of users' motor capabilities and cognitive processes involved in the understanding of how interactive devices work. However, such an approach disregards the complexity of humans' intentional structures. According to Pacherie and colleagues (Mylopoulos and Pacherie 2019), human intentions could be described as nested into hierarchies. For example, a human agent would have a future-directed intention (e.g., "I want to send a message"), that generates a present-directed intention (e.g., "I want *that* smartphone to be in my hand"), that drives the enactment of a motor intention (e.g., "I am moving my hand *this way* to grab the smartphone").

Focusing on usability of interfaces, one could be led to consider the motor components only and disregard the role of the reasons why people actually *do* things with technologies. On the contrary, research has even demonstrated that usability of an interface changes depending on the user having or not a specific goal when using the technology (Triberti, Gaggioli and Riva 2016): one who aims to use a technology for specific, personal reasons may identify more severe usability issues than expert evaluators. Consistently, attitudes towards technology (e.g., perceived utility) are influenced by the presence or absence of affordances pertaining to specific intentions the users are currently trying to achieve, and such influence acts at an unconscious level (Triberti, Villani and Riva 2016).

Taking this evidence into consideration, the model referenced above (Triberti and Riva 2015; 2016; Chiappe and Vervaeke 2021) argues that a "perfect" interaction between a user and a technology could be achieved when each level of the user's intentional structure *dovetails* with the appropriate feature of the technology, which could also be represented as a structure (Garrett 2010): any technology indeed has a design concept (i.e., the main purposes it should fulfill), which informs a set of specific functions (i.e., the actions one could perform when actually using it), which defines the physical interface, made of symbols and interactive devices (e.g., icons, buttons, levers).

Taking into account all levels of intentions/technology dovetailing would allow a user experience evaluator to identify usage issues that do not pertain directly to usability of the interface but, for example, to technology misuse or designers' failure to understand the users' real needs. In the present contribution, the reference to the concept of intentions-technology dovetailing is useful to deepen further the phenomenon of the sense of presence in VR. When one immerses within a simulated environment, they are not in a "vacuum", rather they tend to enact a complex structure of intentions. If the VR is characterized by a compelling content and meaning, this will help the user to develop and enact future-directed intentions; if the VR gives the *impression* to be responsive to actions that would descend naturally from future-directed intentions, this would help the users to structure present-directed intentions into clear and specific action plans; if the

interface is vivid, realistic, responsive, interactive, the user will be able to implement motor intentions and to receive feedback from the virtual environment. According to this perspective, the sense of presence is influenced by the perceived possibility to implement intentional hierarchies in full, to act freely and naturally in the environment, which extends beyond the mere "moving" without a clear purpose or understanding of the context. Even this conception highlights the role of psychological factors in the generation of sense of presence, attributing less value to technical or graphical aspects of VR.

Conclusion

This paper challenges the conventional technology-centric understanding of presence in virtual reality, presenting evidence for a more nuanced, psychologically grounded conceptualization. Our analysis demonstrates that the sense of presence emerges from a complex interplay of three key dimensions: narrative context, individual-social factors, and intentional structures. This reconceptualization has significant implications for both research and practice.

First, measuring presence requires moving beyond simple technical metrics to assess how users' personal characteristics and motivations shape their perception of virtual environments. Second, developing truly immersive experiences demands equal attention to narrative and contextual elements as to technical features. Third, virtual environments must provide affordances that align with users' complex intentional hierarchies—from broad goals to specific actions.

Looking forward, we propose three priority areas for future research:

1. Investigation of how narrative and emotional elements in virtual environments affect presence across different application domains
2. Development of personalization approaches that account for individual and cultural variations in presence experiences
3. Integration of predictive coding frameworks to better understand how users' intentions and expectations shape their sense of presence

This more sophisticated understanding of presence is not merely theoretical—it has practical implications for the growing adoption of VR in sensitive contexts like healthcare and education. By moving beyond technical considerations to embrace psychological and social dimensions, developers can create more effective virtual experiences that achieve their intended outcomes while accommodating individual and cultural differences.

Data availability

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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Note

1 https://www.statista.com/statistics/677096/vr-headsets-worldwide/

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S.T. conceived the ideas presented in the article and wrote the first draft. C.S. participated in writing the first draft and in review. G.R. participated in conceptualization, review and supervised the whole process.

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The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors, therefore ethical approval was not required.

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