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The Many Dimensions of Us: Harnessing Immersive Technologies to Communicate the Complexity of Human Experiences

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EDITORIAL

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Immersive Storytelling as a Technology, a Practice, and an Experience

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Abstract

This thematic issue explores the transformative potential and challenges of immersive storytelling through extended technologies. While these technologies have been hailed as potential "empathy machines" that will encourage perspective-taking and understanding of others, they have also been critiqued for being distracting or engaging in identity tourism. Essays in this collection further demonstrated the complexities of extended reality storytelling. Collectively, these essays reflect ongoing dialogues about the efficacy of extended reality in conveying meaningful narratives, urging a nuanced understanding of technology's role in storytelling. This collection serves as a catalyst for future explorations into where and how to craft immersive narratives for impact.

Keywords

augmented reality; empathy; extended reality; participatory design; virtual reality

1. Introduction

From charcoal and berries on dark and cavernous walls to digital pencils and capacitive tablet computers, communication technologies exert a profound impact over the form and content of the stories we tell (Schramm, 1988). Here, the emergence of metaverse technologies (such as virtual and augmented reality) represents a potentially profound means for enhancing the veracity, artistry, and impact of these stories.

At the same time, this technological emergence also poses unique challenges for how we create and share narratives of the experiences of a wide range of people. Much of our expertise is based on “screen-based storytelling” such that we usually tell *stories in rectangles* but bleeding edge technologies take users into the screen, requiring us to understand how to tell *stories in spheres*. Amidst initial promises that extended reality technologies would be “empathy machines” (Milk, 2015), there have been numerous challenges about overpromising in this respect (Sora-Domenjó, 2022)—such as concerns about identity tourism and false empathy (Nakamura, 1995) or considerations about the taxing and demanding nature of interacting with immersive worlds (Bowman, 2021).

Our thematic issue invited scholars and creatives from a variety of epistemological and practical backgrounds to directly engage with questions around the efficacy and limitation of using extended reality to create and deliver meaningful and impactful stories. To some extent, the notion of “immersive storytelling” is somewhat of a misnomer in that it conflates narratives with the technologies used to deliver those narratives; it confuses “being in a story” with “being in a place” (see Pressgrove & Bowman, 2020). That said, the articles collected here show consistently that the medium through which a story is told can have a profound impact on how those narratives are engaged. Below, we preview a few of the offerings in this collection, and we encourage you to directly read them all.

2. Storytelling and Empathy

Several of our manuscripts were focused on fostering a sense of empathy and perspective-taking among VR users. For example, Vázquez-Herrero (2024) argues convincingly that established approaches towards immersive storytelling privilege the former term over the latter, leading to a form of technological determinism that seems to undermine the critical role of narratives in storytelling. This article reminds us that while technologies do unlock new affordances for how stories are created and engaged, we should ensure that “technology is at the service of the story.”

Two empirical data collections somewhat bear out Vázquez-Herrero’s (2024) claims. Martínez-Cano (2024) compared a 2D and 360° virtual reality (VR) video to deliver a narrative about a school-aged student being bullied because of their gender identity to understand if and how this content would encourage empathy via self-reported and physiological measures. Across these measures (and admittedly with a smaller sample size), they found no such effects, such demonstrating that the use of extended reality technologies alone was not enough to simulate significant variance in empathy. More telling is that the 360° VR video was initially more engaging, but not enough to foster engagement with the narrative (and thus, empathy for those in the narrative). Likewise, Green et al. (2024) employed self-determination theory to better understand how audiences engage with IDEA-themed content via 360° VR (inclusion, diversity, equity, and accessibility). Through a rigorous methodology that included quantitative and qualitative data, their findings raised possible drawbacks in that users often expressed feeling a *lack* of autonomy, competence, and relatedness with content and instead, often felt like voyeurs within the space (conversations about Alzheimer’s, blindness, and living in a refugee camp). Likewise, perspective-taking was often less about one’s own perspective but rather, considerations of close others (noting that self-differentiation is a key to empathy, see Bowen, 1978).

Of course, we also see data that does support the efficacy of immersive storytelling to foster intended effects. Shin and Lee (2024) used monoscopic 2D compared to stereoscopic 3D footage of environmental concerns, such as damage to coral reefs due to nearby taro farms. Their findings were somewhat complicated in that they revealed curvilinear rather than linear relationships in which message credibility decreased as presence increased initially, but increased once presence was intensified (i.e., after an initial dip). Among other effects that we encourage you to explore in the manuscript, the article shows a complex but still compelling use of stereoscopic 3D to potentially encourage more careful consideration of the environment. Such effects are especially relevant as they suggest that immersive storytelling techniques are especially relevant when space and places are key to the narrative being told (see Barreda-Ángeles et al., 2024).

Very much in this same frame, and pulling from his own award-winning work *Body of Mine* (https://www.bodyofminevr.com), Kostopoulos (2024) sought to empirically validate the extent to which embodying a viewer in the body of a transgender person could directly foster empathy by encouraging a more compassionate engagement with gender dysphoria. Their data demonstrate that users self-reported a better understanding of gender dysphoria, identifying more closely with trans people, and supporting a general notion that people should be free to decide and change their gender, among other results.

3. Immersion Into Other Narratives

Not all stories are designed to foster empathy, and several essays in our thematic issue feature different applications of immersive storytelling. For example, Bustos-Lopez et al. (2024) describe specific elements of user experience and extended reality that are key to helping designers better understand how to craft spaces in the context of transformable architecture. Girginova et al. (2024) likewise advocate for a process of research through design, suggesting that self-identification and empathy between audience and content can be fostered through participatory design processes, especially when focusing on augmented reality campaigns. Their manuscript provides a readily replicable “research through design” framework with numerous examples for the curious reader. Han et al. (2024) likewise demonstrated that one way to improve engagement with VR (and to potentially counteract barriers to these experiences) is through a scaled approach that gradually introduces them to the technologies that they will be engaging, as compared to written or non-interactive video techniques.

While this technology was viewed overall quite positively in the scope applications above, Greber et al. (2024) found that audiences were less enthusiastic about the use of the same technologies for journalistic news. One of the more compelling findings from their study is that while immersive journalism did not influence knowledge of events per se, it did lead to greater perceived knowledge, which might point to an unanticipated “credibility paradox.” One of their implications was that such uses might not be suitable for informing audiences, but could be highly useful for situations in which it is important for audiences to feel like they are *part of the story*. Such claims are explored in more detail within their manuscript. In all of this, Kukshinov (2024) reminds us to avoid being seduced by a technologically deterministic approach in presuming that immersive media will de facto improve the impact of stories and likewise, he notes that even comparatively “low-tech” solutions are highly effective at fostering empathy and perspective taking—after all, immersion is a psychological state rather than an inherent feature of technology. Thus, we have to consider the stories being told, the users engaging those stories, and ultimately which modalities are most effective for helping the latter engage the former.

4. Conclusion

These essays were motivated by a companion event hosted by the S. I. Newhouse School of Public Communication—Advances and Opportunities in Immersive Storytelling Technologies (https://newhouse.syracuse.edu/research/newhouse-summit-2024). At that event, and in these essays, we see critical discussions about the past, present, and future of immersive storytelling through extended reality technologies. Just as the development of those technologies shows no signs of slowing, our individual and joint interest in communicating authentic and meaningful stories about the world around us endures. We hope that the essays selected for this thematic issue inspire each of us to critically reflect on and more deeply engage with the intersections of immersive technologies and narrative.

Conflict of Interests

The authors declare no conflicts of interest.

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ARTICLE

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Immersive Stories: From Technological Determinism Towards Narrative Determinism

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Abstract

Following the wave of immersive production that occurred between 2015 and 2018, and in the face of new virtual, augmented, and mixed-reality devices, this article discusses the need to move from a technology- or device-focused perspective in the analysis and use of immersive technology towards a story-focused or story-first perspective. It starts with a technological perspective, contextualising the evolution of immersive technologies and their interpretation from a technological determinism point of view. Secondly, the ecological perspective provides an integrative reading of the technique, its use, and its experience, based on the concept of the environment. Finally, and after acknowledging previous research on the effects of immersive media on the audience, the article considers the narrative elements that are reinforced by immersive technologies in journalism and nonfiction, based on the qualitative analysis of projects. The article highlights narrative resources associated with the social character of the story, the spatio-temporal framework, and the emotional impact. It suggests a shift towards “narrative determinism,” which would allow us to analyse and employ immersive resources in terms of their contribution to storytelling and to overcome the limitations of perspectives that are highly dependent on specific platforms or technologies.

Keywords

immersive storytelling; immersive technology; journalism; narrative; virtual reality

1. Introduction

In the early days of immersive digital media, an ecological view described the immersive medium as a sensory environment, as the medium that could probably most effectively extend human senses.

Hybridisation and experimentation both demand adaptation, keeping in mind that the human being is a narrative being. Therefore, in the construction of meaning and memory, immersive technologies emphasise the most powerful narrative elements to represent human complexity, although audiences have historically experienced immersion in other forms of expression such as literature, theatre, radio, television, or cinema.

This article discusses the need to move from a technology- or device-focused perspective in the analysis and use of immersive technology (virtual reality [VR], augmented reality, mixed reality) towards a story-focused or story-first perspective. Technology is still interesting and relevant, but there is a risk of falling into circumstantial assessments, circumscribed to very specific moments and defined by the existence of a particular technology or device.

Previous literature has studied the effects of comparing formats and devices (e.g., Kelling et al., 2019; Shin & Biocca, 2018; Van Damme et al., 2019), studying user immersion (de Bruin et al., 2022) or empathy (Sánchez Laws, 2020), and considering a psychological perspective (Bowman et al., 2021). This article aims to discuss the narrative elements reinforced by immersive technologies in journalism and nonfiction, based on a historical and conceptual review and on a qualitative analysis of immersive projects. The article highlights aspects such as the social character of the story, the spatio-temporal framework, the emotional impact, and its study. It identifies challenges and limitations that hinder the arrival of a narrative determinism in this field that would facilitate its consolidation and projection, in the face of the pressures and barriers imposed by technical novelties.

2. A Technological Perspective

In the first instance, the technical dimension will be reviewed, which is mainly reflected in the devices used to access immersive experiences. Starting with the concept of immersion, the steps that immersive technology has taken are examined through the perspective of technological determinism.

Immersion is a polysemous term of Latin origin (*immersio*) that means, strictly speaking, to entirely submerge a solid body in a liquid. In this context, we understand immersion as the ability to situate, surround, and involve the user in the reality represented. This has also been interpreted by different authors who speak of telepresence (Steuer, 1992), being there (Heeter, 1992), or first-person experience (de la Peña et al., 2010), meanings that appeared in initial research on technologies that facilitated the immersive condition in the 1990s. Consequently, immersive technologies are those that produce this stage of immersion, making the users feel that they are in a place, a time, a specific reality. To this end, these technologies transmit information that replaces the sensory perception of the physical world—for example, images through headsets, sound through headphones, vibrations through gloves or remotes, and other sensory effects.

Immersive technologies are classified according to the degree of integration of the information they introduce (virtual world) and the stimuli of the reality that surrounds us (physical world), and three levels are established. First, when the virtual level replaces the physical level for the most part we speak of VR. In the words of Steuer (1992), this is an environment in which the receiver experiences telepresence. Secondly, when there is an overlay of the virtual plane on the physical plane, through glasses or screens, we refer to augmented reality. That is, a type of VR in which the response to stimuli is superimposed on real-world objects (Sherman & Craig, 2003). Thirdly, when there is a combined integration of virtual and physical planes, with interaction between the two—for example, with physical objects or spaces intervening in the virtual world—we speak of mixed reality: “the incorporation of virtual computer graphics objects into a real three-dimensional scene, or alternatively the inclusion of real world elements into a virtual environment” (Pan et al., 2006, p. 20).

However, apart from these three categories, technology acts in other, perhaps less sophisticated, dimensions where it also generates immersion. The search for this resource has been pursued in audiovisuals with sound environments or on the web with continuity effects such as parallax, or interactivity and personalisation of the story (Sirkkunen et al., 2021; Vázquez-Herrero & van der Nat, 2023; Wang & Sundar, 2018).

Ideas of immersion and VR have always been closely linked to devices and systems: “Since immersion depends on vividness, its factors are closely related to the devices that lead to realism in representation” (Ryan, 1999, p. 112). A specific case such as VR has often been defined in relation to a particular technological system (Steuer, 1992).

Immersion began to develop with stereoscopic vision and panoramic projection technologies, including Wheatstone’s stereoscope (1838), Brewster’s portable stereoscope (1849), Louis Ducos du Hauron’s anaglyphs (1891), Raoul Grimoin-Sanson’s Cinéorama (1897), the panoramic and immersive cinema of the mid-twentieth century, and Hugo Gernsback’s teleyeglasses (1963). Progress continued to be made towards head tracking with lateral (panoramic) and absolute (3-axis) positioning. The key contribution here was Ivan Sutherland’s Sword of Damocles (1968), the first viewing helmet with orientation detection of the wearer’s point of view. Surround sound reached its highest level with binaural sound, which allows us to locate sound in space.

On the more physical level, immersion attained the introduction of the body into the scene (and mapping the exhibition space), as well as incorporating touch and interaction. In terms of devices that exploited senses other than the visual and auditory, Morton Heilig’s Sensorama (1956) was one of the most striking, as well as Sandin, Sayre, and DeFanti’s data gloves (1977), exoskeletons, and peripherals by VPL and Jaron Lanier (1988). Simulators were also developed, such as Link Trainer by Edward Link (1929), and NASA’s Virtual Environment Workstation in the mid-1980s. Finally, the design of CAVE and fulldome systems gave rise to immersive and multi-user spaces.

From the 1990s onwards, the development of immersion turned to the World Wide Web with the integration of 3D models and later the HTML5 standard and libraries such as WebGL. In 2012, Palmer Luckey launched a crowdfunding campaign for the first Oculus prototype of a VR headset for immersive 3D gaming. In 2015, this product line began to explode causing, consequently, an increase in available content. The performance of 360-degree cameras and headsets also improved, with controls, gesture detection, and interaction with the physical space; and mixed-reality devices appeared (Microsoft Hololens, Magic Leap, among others). In February 2024, Apple’s Vision Pro was launched, which, as on previous occasions, attempted to define a product category: a “spatial computing” mixed-reality device that, as its promotional video demonstrates, intends to change everyday tasks and generates new interactions between physical and virtual space.

This summarises the evolution of technologies that, for the most part, and in keeping with the way technology evolves, did not consider storytelling as a main objective, but rather military, industrial sector, and educational simulation. In the 1990s, initiatives emerged in American universities to experiment with immersive technologies applied to journalism and documentaries—for example, the 360-degree documentaries (Pavlik, 2001), the I4 project (McLeod, 2003), and the works of the Immersive Journalism team led by Nonny de la Peña, such as *Gone Gitmo* and *Hunger in L.A.* in 2007 and 2012 respectively. It was then that immersive journalism was defined (de la Peña et al., 2010), in a conception closely linked to the device—such as CAVE or head-mounted display. Later, the term immersive journalism would be used for a wider variety of resources of immersive rhetoric (Domínguez-Martín, 2015) and would be the protagonist of a brief but fruitful stage of experimentation between 2015 and 2018: "As technological developments have propelled journalistic VR out of university labs and research institutes, experimentation has blossomed" (Mabrook & Singer, 2019, p. 2096). Subsequently, this immersive hype, which generally translated into 360-degree videos (Sirkkunen et al., 2021), faded (López Hidalgo et al., 2022). When the hype died down, production returned to an experimental and creative level, albeit limited in volume by low penetration of consumer devices—Alsop (2023) estimates 34 million VR headsets have been sold worldwide, based on 14 million in 2020.

We are currently at an early stage where the technology is advancing much faster than its adoption in society. In barely a decade, we have seen the commercialisation of numerous VR headsets towards a certain democratisation of access to such devices. While VR is still a niche category, without widespread popularity, the technology continues to advance and differentiate itself in terms of technical issues if not in the way it is used.

At this point, we can interpret the development we have seen so far in immersive technologies from the perspective of technological determinism. This concept assumes that technology is the basis of human activity and that it has the capacity to influence society, although it has been approached with varying degrees between the causal technology–society link proposed by sociologist Thorstein Veblen and softer positions. In the field of communication and following McLuhan (1962), technological determinism shapes our social activity, and, for this reason, we communicate in whatever the medium of the moment is. It is evident that "media and technologies 'mediate' the world for us in each of our interactions" (Islas & Arribas, 2023, p. 265). Indeed, authors such as Smith and Marx (1996) consider that this sense that technology has power as an agent of change is part of the shared body of knowledge, especially from one's own experience with technology, when the user realises that they are subjecting any activity to transformation. This is no minor issue now that we are seeing the effects of automation and artificial intelligence in our lives and the latest launches of spatial computing headsets.

Theoretical discussions of technological determinism have argued for a technology that develops autonomously, capable of an out-of-control history-shaping process (Winner, 1977) and of determining social change (Kline, 2001), confronting social constructivism. Deterministic discourse elides human intention and defines new media technologies as revolutionary and transformative (Drew, 2016). Conversely, technological determinism has been criticised (Williams, 1977), especially when referring to social processes such as communication. With optimistic and critical views, technological determinism considers that technological innovation is a determinant for society (Saperas, 2018).

The journey completed by immersive technology can be interpreted from a determinist perspective because it has generated changes and needs in society, with disruptive proposals for experimentation, entertainment, and communication. Immersive technologies have been shaped as another medium and, in this sense, they manage to influence society. On the other hand, until now more attention has been paid—by academia and beyond—to technique than to cultural uses and audience participation, which are fundamental elements in the field of narrative.

In the following section, I consider media ecology, a scientific discipline that includes technological determinism but articulates a broader and more integrative view through the concept of environments.

3. An Ecological Perspective

Media ecology is a generalist theory (Scolari, 2010) and a complex and systemic meta-discipline (Islas, 2015) that studies media as environments. While it is applicable to any form of communication, I consider the immersive field to be particularly relevant to analyse from this perspective—explored previously by Horrocks (2004) and Rubio-Tamayo et al. (2017)—because it is itself based on placing the user in an environment (a place, a space, a scene). Earlier we observed the evolution of immersive techniques through technological determinism—this is a concept that has also been situated within media ecology, in the work of figures such as Marshall McLuhan. However, the ecological vision goes further and puts forward another perspective in which the media—in this case immersive is considered another medium—are species in an ecosystem in which they relate in multiple ways to other species, since "no medium exists alone or has meaning alone, but in permanent relation to other media" (McLuhan, 1964).

So-called precursors of media ecology—such as Eric Havelock, Lewis Mumford, Jacques Ellul, and Harold Innis—have presented an ecological perspective based on the analysis of communicative processes and mediating technologies, in some cases based on technological determinism. The most prominent name of the Toronto school, Marshall McLuhan, insisted on the conception of the media as environments, alluding to the immersion of the user, and the uses and effects caused by each medium. It is precisely this vision that is most appropriate for interpreting what today's immersive technologies are: an environment in which the user is immersed and whose aim is to be as unnoticeable as possible, to achieve a symbiosis that eludes the physical world around us and leads us to an experience. The immersive medium is likely the medium that most effectively extends the senses of the human being, in a similar way that mobile devices have been considered authentic extensions of the body (Renó, 2015).

However, the ecological vision must also consider that the immersive medium appears in a media ecosystem where other consolidated media—such as the press, radio, television, and digital media—already exist. Marshall McLuhan and his son Eric worked on systematising the analysis of media ecology and proposed the tetrad of media effects (McLuhan & McLuhan, 1988), the closest approach to a scientific analysis model (Scolari, 2015). This tool poses four questions to understand the evolution of media: What does the medium enhance? What does it make obsolete? What does it retrieve? What does it reverse when pushed to extremes?

Applying the tetrad to the immersive medium, it is observed that it extends several senses, mainly visual, auditory, and tactile, but also reinforces the interactive faculty to bring us closer to an immersive experience. As a non-consolidated medium, it has not led to the substitution of other media, but it limits the use of some devices and competes for the space of some mobile devices, consoles, television, and computers. What the immersive medium recovers is ritual, the multisensorial representation of a reality with a physical and participatory component (agency); it tries to assign a central role (embodiment) in a digital performance.

Taken to the extreme, it reverses the exploration of collective forms of consumption, a new turn from the individual to the social—albeit very limited for the moment—and from the individual single-device experience that has progressively established itself towards custom-created exhibition spaces (installations and museums) that are sometimes shared.

Following Logan (2010), a media ecosystem is made up of different elements: humans, media, interaction and communication technologies, and languages. Of these, language is fundamental in an immersive medium to represent reality and take advantage of immersive conditions; but it is also disruptive compared to consolidated media and is still in its infancy (Domínguez, 2017). With regard to the other three elements, and returning to McLuhan (1962), every technology tends to create a new human environment; what the immersive medium creates is experience, a process rather than an outcome: “a fluid and reflective concept, rather than a fixed and isolated factor” (Shin & Biocca, 2018, p. 2815). Immersive technologies provoke effects on the reception of messages, which result in the experience, so that users become a participatory, engaged, and proactive audience.

Those effects were partially tested in previous literature. Studies on immersive journalism and nonfiction demonstrate effects on the role of the user, who has the opportunity to become a reporter and decide how to look or focus their attention (Jones, 2017), and on their sense of presence (Cummings et al., 2022; de Bruin et al., 2022; Van Damme et al., 2019; Vázquez-Herrero & Sirkkunen, 2022). The immersive experience also affects enjoyment (Van Damme et al., 2019) and is affected by the device, the users’ traits, and contexts (Shin & Biocca, 2018). But the consequences of consumption in the environment generated by immersive technologies go further and relate to higher empathy (Sánchez Laws, 2020; Shin & Biocca, 2018; Vázquez-Herrero & Sirkkunen, 2022), deeper knowledge (de Bruin et al., 2022), and the reinforcing of news credibility (Kang et al., 2019). Convenience has been assessed—with gratifications identified for their use (Mabrook & Singer, 2019)—while ethical risks and critiques of the use of immersive technologies in fields such as journalism have also been identified (Palmer, 2020; Rose, 2018; Sánchez Laws, 2020), although several studies have focused their analyses on a comparison between technologies, devices, and formats.

Following McLuhan (1964), the idea that “the medium is the message” is evident in immersive media because the experience resulting from the use of immersive technologies has the potential to reinforce a message and generate associated emotions that promote agency. However, while I believe that the immersive medium is—as a technology—important, I believe that the content should not be undervalued. Following Miroshnichenko (2016), contemporary media—including immersive media—are not just information carriers but can create reality. In the face of accelerated technological innovation, we should look for values that resist constant change and focus on creative and narrative aspects, as discussed in the next section.

4. A Narrative Perspective: Narrative Elements at the Core of Immersive Stories

This third approach aims to go beyond the first wave of research focused mainly on early generally limited immersive works and today’s somewhat more evolved and diverse works. It proposes a story-first approach to the analysis and production of immersive stories in journalism and nonfiction, in order to prioritise narrative over technology and to continue advancing in knowledge and creation independently of a specific technology. It is, therefore, a proposal with an eye on the contribution that is made to the narrative, being more platform- or technology-agnostic.

The "storytelling-narrative dimension" is one of the factors associated with VR—as an immersive technology—through the narrative of the virtual environment and the story that users create through interaction (Rubio-Tamayo et al., 2017), for example, through immersive features in the narrative such as the user being active or passive in the story (de Bruin et al., 2022). Previous studies on the relationship between immersive media and narrative conclude that there is a challenge to narrative conventions (Domínguez, 2017) and a redefinition of classic narrative elements.

Paíno Ambrosio and Rodríguez Fidalgo (2021) proposed an immersive communication model—individual and multi-user—that considers the changes caused by the incorporation of immersive technology in communicative processes, including the multimedia construction of the message as well as the user's decision-making—and deepening—capability. Another contribution to immersive narrative comes through the virtuality–reality continuum, where Rubio Tamayo and Gértrudix Barrio (2016) integrate the concepts of embedded and emergent narrative, differentiating between that which is pre-established and that which emerges from user interaction. However, immersive formats coexist with other traditional formats (video or text) and between them, there is no disruption, rather they form part of the same continuum of emotionality and rationality (Vázquez-Herrero & Sirkkunen, 2022).

The contribution of immersive media to narrative is associated with different aspects, among which space is a key point, as a simulation of a reality, using places as narrative strategies and through dialogue with space (Kukkakorpi & Pantti, 2021); but also because of the relevance of surrounding action when generating content (Vázquez-Herrero & López-García, 2017). The sensation of presence is a condition closely linked to space and one of the main features attributed to immersive media (de Bruin et al., 2022; de la Peña et al., 2010). On the other hand, the emotional dimension is connected to the narrative form (Greber et al., 2023a) and is reflected in empathy and embodiment (Shin & Biocca, 2018), audience involvement and engagement (Vázquez-Herrero & Sirkkunen, 2022), and by placing the user at "a paradoxical threshold between proximity and distance" (Ceuterick & Ingraham, 2021, p. 9). This enhancement of the sense of presence and emotional arousal implies more constraints for processing the information in the story (Barreda-Ángeles et al., 2021; Vázquez-Herrero & Sirkkunen, 2022). However, emotionality raises criticisms of the concept of VR as an "empathy machine" in fields such as journalism (Jones, 2021)—where impartiality and ethics also play a role—or prosocial storytelling—whose effect does not come directly from the use of immersive technology but through an engaging narrative (Pressgrove & Bowman, 2020). Therefore, the study of aspects related to narrative development in the immersive medium is crucial for overcoming the more technological view. Recent projects of diverse natures—beyond 360-degree video and basic VR—are presented below, with a focus on how the story is told through immersive media and how those resources contribute to representing reality.

The spatio-temporal framework takes centre stage when the immersive medium transports us to a distant, unknown, inaccessible, or particularly significant place or moment. This is the main value of many 360-degree videos that transport us to places where catastrophes have occurred, such as in *Fukushima, Contaminated Lives* (2016), war conflicts in *The Fight for Falluja* (2016), or remote places in *Ecospheres* (2020). *Home After War* (2019) shows a home in Fallujah (Iraq) after the city was under the control of Islamic State, through a room-scale interactive experience where the space was captured with photogrammetry. The user explores the house by moving through it and sees for themselves the state of destruction of the place. Another possibility is to represent a historical event and take the user back to the exact moment (*JFK Memento*, 2023). In these projects, the space is a central element of the story and the possibility of placing the user in the scene reinforces the storytelling, as these are exceptional situations or places that provide an account of a reality.

With a much more physical dimension, *Carne y Arena* (2017) is a project defined by its director Alejandro G. Iñárritu as "semi-fictionalised ethnography" and based on an installation with several spaces to address the human condition of migrants and refugees. The experience represents the journey of a group of migrants crossing the US–Mexico border. It has five spaces where each visitor individually puts themselves in the place of the migrant: the access room, the freezer, the desert, the cell, and the exhibition. There are several spatial elements that have a narrative value in the experience; for example, the freezer is a refrigerated container where the "migrant" takes off their shoes and learns the story of the shoes that are left abandoned around the border fence; the temperature is low, there is constant ventilation, and all the elements are cold. On the other hand, the crossing through the desert occurs in a room with a sandy floor and a strip of dim orange light that simulates the sunrise; it is at this point that the user visualises the central scene with a VR headset, with freedom of movement around the room, sound effects, a higher temperature, and wind. This is one of the most complete immersive experiences to date and the narrative use of space is one of the key elements.

The social character of the story is an important factor in immersive journalistic and nonfiction stories that show ways of life and social debates about racism (*MLK: Now Is the Time*, *Travelling While Black*), living conditions (*We Live Here*, *Dreaming of Lebanon*, *Clouds Over Sidra*), migration and displaced people (*The Key*, *Carne y Arena*), and health and inclusion (*Goliath: Playing With Reality*, *Notes on Blindness*). A narrative resource employed brilliantly in some projects is the construction of the character in such a way that the user can get to know multiple edges of a person's complexity to better understand their reality. *We Live Here* (2020) tells the story of Rockey, a homeless person living in a tent in a park, from which she is evicted without her personal belongings. The user can move around inside the tent and, by interacting with the objects, learn about the protagonist's life, fragments of her past, and some of her dreams in order to understand the present and the difficult situation she is facing.

Immersive experiences seek a direct relationship with the user through first-person testimonials that look the user in the face. In *Home After War*, Ahmaied tells the story of his family's return home after the end of the fighting; his voice is activated when the user approaches and looks towards him in the different rooms. *Dreaming of Lebanon* (2023) is defined as an "interactive VR documentary" in which Rafik, Josephine, and Batoul tell the story of the challenges of living in a country in crisis. The user dialogues with each protagonist by choosing the questions, sitting face-to-face with them. In this way, the testimonies converse directly with the audience and bring them into the scene, similar to breaking the fourth wall in cinema.

In order for the user to put themselves in someone else's shoes—a matter directly related to the much-discussed empathy—a narrative must accompany the technology. We see this in the aforementioned *Carne y Arena*, where the audience literally puts themselves in the shoes of one of the migrants who crosses and is captured, with the police pointing directly at them, feeling their heartbeat. *Notes on Blindness: Into Darkness* (2016) narrates John Hull's experience of blindness from the tapes he recorded during the process. It uses binaural sound and visualisations—reduced but harmonised—in such a way that the sound gradually uncovers elements of the scene, sometimes ephemerally, until it reconstructs what is happening. Thus, the user puts themselves in the role of a blind person and begins to pay more attention to the sound plane, in the same way as the protagonist. *MLK: Now Is the Time* (2023) recreates Martin Luther King's well-known "I have a dream" speech and contextualises it with a description of the inequalities that underpin the struggle for freedom and equality. The user has several opportunities for interaction that allow them to experience situations of inequality based on race, but the most powerful narrative and symbolic opportunity is in raising their fist in the air to move through the experience.

Narrative resources also extend to the way a narrative is constructed, employing story-like structures, threaded by a metaphor that takes the user on a symbolic journey that engages and progressively uncovers reality. *Goliath: Playing With Reality* (2021) explores the limits of reality and tells a story about schizophrenia and the power of online gaming communities. It employs visual effects and symbolic interactions such as a game in an arcade machine, a shooting game, and various elements that allow the user to hear a voiceover or feel a worm on their hand. Users are asked to record their name at the beginning—sometime later it is used as a resource to effectively simulate voices they hear. *The Key* (2019) is a room-scale experience that takes users on a metaphorical journey in which they interact with various elements to progress through the story. Users progress from dreamlike environments and obstacles to reality—from danger to a safe place—and finally discover that they have been told about the life of a refugee and the key they always keep from home, even though they can never return. The power of metaphor and the final twist are narrative devices far from the usual practices of journalism and nonfiction, but it makes masterful use of such resources to convey the complex reality it addresses.

Finally, it is worth noting that concluding twists have also been used in other projects. *Home After War* incorporates an explosion effect that surprises the user who was calmly navigating the home in Fallujah. *We Live Here* employs animation and overlapping sound layers to mark the transition from the interior of the tent, where the user was learning Rockey's story, back to the reality of the eviction. We could refer to an "awakening" that causes a disruptive transition between the experience in which the user is immersed and a revealing ending, which places or returns them to the real context of the story.

The aforementioned resources, although often used in immersive media, have been implemented in other narrative media. Thus, the introduction of perspective in painting (Ryan, 1999), the construction of characters, rich descriptions, or the use of testimonies in narrative (Allan, 2019), and the fourth-wall break in television and cinema (Auter & Davis, 1991), as well as metaphors, symbolism, and narrative twists have all been widely employed to captivate the audience. What we see here is a new approach to immersion using familiar techniques, as the quest for audience immersion is a long-standing desire of any form of expression.

5. Conclusion

The study and use of immersive technologies has been closely linked from its beginnings to a technological determinism through which the evolution of techniques and devices generates change in society; however, the mere appearance of a technology does not mean that the public will adopt it (Pacheco, 2023). After revisiting this vision and the ecological perspective, in which the immersive medium generates a new environment and functions as an extension, a shift towards a story-first approach is suggested. This sort of "narrative determinism" would make it possible to analyse and use immersive resources considering their contribution to the telling of a story. This suggests overcoming the limitations of perspectives that are highly dependent on specific platforms or technologies, especially considering that these are increasingly diverse: "There will be no single medium that absorbs all others; instead, different media will continue to flourish, each augmenting different aspects of our daily lived experience" (Bolter & Engberg, 2017, p. 154).

At present, the volume of immersive nonfiction production is limited, following the hype of 360-degree video and VR that occurred between 2015 and 2018. Platformisation is also playing a notable role in this field, where the most popular devices are concentrated in a few brands such as Meta—which acquired Within, one of the most successful cinematic VR distribution applications, and closed it in February 2023 to bring access to content under the Meta Store. At the same time, technological changes demand constant updating; for example, the National Film Board of Canada announced that *The Enemy* would no longer be available online because technology is moving so fast, and they are promoting an archive to preserve digital creations that become obsolete.

Research to date has focused on technological and production aspects of immersive experiences, in a fast-changing context in which well-functioning low-tech projects coexist with a certain fascination for technical sophistication, despite not reaching a mass audience. The focus in recent years has shifted from technique to experience, effects, and ethical challenges. However, revaluing the narrative contribution of immersive media is a shared concern of other researchers, who call for the need to "continue building theoretical approaches regarding narratives and storytelling for these new media" (Rubio-Tamayo et al., 2017, p. 15) and suggest "future productions—in addition to creating a plausible IJ [immersive journalism] experience—focus on storytelling" (Greber et al., 2023b).

The article has highlighted narrative resources in relation to spatio-temporal framework, the social character of a story, and the emotional impact, in order to underline the shift towards narrative determinism. This approach should also contribute to ensuring that technology is at the service of the story, that its contribution reinforces the narrative and is not a mere technical asset, avoiding relying on sophisticated and flashy gimmicks where the story remains in the background. The purpose has not been to systematise the construction of immersive stories, but to contribute to this field of study with a consideration of three perspectives (technological, ecological, and narrative) and some notions about the impact of the immersive medium on narrative. Future lines of research should take steps towards a deeper but also integrative understanding of journalistic and nonfiction narratives through interactive and immersive media.

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ARTICLE

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Unestablished Boundaries: The Capabilities of Immersive Technologies to Induce Empathy, Tell Stories, and Immerse

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Abstract

This article presents a critical viewpoint on the existing research to establish the boundaries of immersive technologies, such as virtual reality, exploring distinctions between sensorial and mental experiences and highlighting the influence of technological determinism in this scholarly domain. The analysis reveals a lack of established conceptual structures for categorizing distinct types of immersion, emphasizing that immersion is not universal and is not inherently technological. In particular, it highlights that, fundamentally, immersive technologies are not designed to immerse into narratives. As a result, this article suggests a dual cognitive framework of immersion to explain the nature of different immersive experiences. The article also critically addresses ethical concerns related to identity tourism and argues against the oversimplification of complex psychological processes, emphasizing the overreliance of the existing studies on visual or technological stimuli. To avoid this, the article suggests a way to avoid technological determinism in relevant conceptualizations. Overall, the article scrutinizes the assumptions associated with immersive technologies, offering insights into their capabilities to stimulate senses and vividly inform, contributing to a nuanced understanding of their effects and ethical implications.

Keywords

immersion; presence; storytelling; technology; virtual reality

1. Introduction

Research on immersive technologies (such as virtual reality [VR]) is dominantly based on technologically deterministic assumptions. These assumptions arise from understanding immersion solely as a quality of the technology (Cummings & Bailenson, 2016). Examples include equating immersion with simply wearing the head-mounted display, or HMD (Shen et al., 2021). These deterministic assumptions may also reduce embodiment to the mere use of an avatar (Li & Kim, 2021), even though embodiment, as a sense of owning the virtual body (Forster et al., 2022), involves multiple elements beyond avatar attributes (Gonzalez-Franco & Peck, 2018). Another assumption is that using a first-person avatar makes users "someone else" by sharing identities and/or bodies (Li & Kim, 2021; Tan et al., 2022), e.g., of an ethnic minority (Chen et al., 2021). However, there's no evidence to suggest users become someone else; individuals remain the same people with their own selves and biases (Yee & Bailenson, 2007). By doing this, many VR studies also overlook the ethical side of their research. In particular, by placing users into "bodies" of someone else, "immersive" technologies potentially promote identity tourism, as a superficial play with identities of others (Nakamura, 2013), instead of true perspective-taking. All these issues also stem from an overarching approach that doesn't differentiate between mental and sensory (immersive) experiences.

In the end, this is an outdated approach that the communication field overcame by rejecting the linear model of communication and technological determinism (Hall, 1973), and this is what immersion (technologies) scholarship should overcome because technology does not tell us how to feel; instead, we process and interpret the incoming stimuli (Shaw, 2017). This may also include the exclusion of the term "immersive technology" from everyday use and replace it with a term that describes what these technologies factually do, instead of what users are expected to feel. The following article also advocates for diversifying the concept of immersion based on the type of experiences, differentiating between sensory and mental immersions, which would help to encompass diverse media interactions. To further promote understanding of the differences between different immersive experiences, I suggest that sensory and mental immersions should be connected to presence and narrative engagement, respectively. Overall, this would mean excluding narratives as objectives of the presence research to facilitate a clearer distinction between different types of immersion and experiences, as well as their effects and determinants.

2. Immersion Is a Psychological State, not a Quality of Technology (Boundary 1)

Immersion (via technology) is a complex psychological state that depends on various factors. The idea that the quality of the technology by itself can induce a particular experience no matter what the content is, aside from being problematically deterministic, is challenging (Calleja, 2014). Technology alone doesn't create immersion for users. Therefore, it is also incorrect to suggest that some technologies are either low or non-immersive technologies compared to others (Bailey & Bailenson, 2017). Everything depends on the context in which the technology is being perceived. From this and other perspectives, immersion (via technology) is not different from the sense of presence.

Technology plays a role in immersion because (certain types of) immersion is a product of interaction with or perception of it. It does not necessarily matter how well the system is designed, or how advanced it is—it has to be noticed, paid attention to, and perceived. In other words:

> A thing must be not only perceptible, but perceived. And in order to be perceived, a thing must be subject to some minimal allocation of perceptual attention, even if fleeting and non-deliberate. Put plainly, one could not expect to feel present in a virtual environment if one's eyes are shut and ears are plugged. (Murphy & Skarbez, 2020, p. 182)

There are always individual factors in play too, whether it is a mood or some personality characteristics, such as an immersive tendency (Witmer & Singer, 1998). Also, if a person is not open or willing to be immersed via certain technologies, it will not happen (Sas & O'Hare, 2003).

How do we then describe the quality of such technologies? Riecke and Schulte-Pelkum (2015) suggested describing it as "immersiveness" or "the medium's ability to afford the psychological process of immersion" (p. 205). It still does not describe the quality of the technology per se. In the end, this quality arguably refers to fidelity. In most general terms, fidelity is "the extent to which the simulation replicates the actual environment" (Liu et al., 2008, p. 92). This quality differentiates "immersive" technologies, but it does not define what these technologies are and what they do.

While these technologies do not necessarily immerse users or make them someone else, they do objectively *simulate* experiences, environments, activities, entities, and so forth. These technologies produce simulations, or, more particularly, interactive simulations (Brey, 2008; Søraker, 2011). Simulation, in general, models systems (Brey, 2008), or the system of signs from the original behaviour system (Frasca, 2013). Not all interactive simulations are designed to reproduce reality and its cues—although the high-fidelity ones usually do. High-fidelity simulations are supposed to be more "immersive" (Calleja, 2014), which, however, only means that these simulations replicate more sensorial cues compared to low-fidelity simulations.

So, even though it is not as appealing to the industry as "immersive technology," it is more accurate to refer to these technologies as "simulation(al)" (Kukshinov, 2023). In that sense, as a technological domain, simulation is similar to mediation. All media or mediation technologies have the potential to induce a sense of social presence, whether it is an email or a complex teleconference system (Kojima et al., 2021); however, what these technologies de facto all do is they all *mediate* social communication. It is also necessary to remember that VR, and related technologies, are not always supposed to immerse users (McVeigh-Schultz & Isbister, 2022).

As a psychological state, immersion should not be considered a mere "engagement," or a technical occlusion from the real world (as in, e.g., Tran et al., 2019). It is a vague and non-operationalizable approach, which also devaluates the immersion's meaning and significance. The value of immersion, as a conception and a psychological state, lies in its capability to blur or merge experiences between media/technology and the real world (Martínez, 2014; Snodgrass et al., 2013). As a result, something that is not real, whether a location or a social situation, is experienced to some extent as real. However, there are at least two ways for our cognition to "misjudge" reality via immersion like that, which I describe in the next section.

3. Differences Between Sensory and Mental (Immersive) Experiences (Boundary 2)

The possibilistic model of consciousness suggests that cognition consists of perception and imagination that mutually define what is real and what is not (O'Connor & Aardema, 2005, 2012; O'Connor et al., 2005). In short, perception is processing what is "there" to be perceived, while imagination processes what is "not there," or possibilities (O'Connor et al., 2005). For example, when we see an object from one of its sides, we do not assume that nothing exists on the back of this object—we mentally simulate some possibilities of what it can be. So, we make sense of reality with both imagination and perception. Therefore, there are at least *sensory* and *mental* ways not only to "judge" but also to "misjudge" reality.

For example, we can misperceive reality via illusions (Ramakonar et al., 2011). Presence, as a perceptual illusion of non-mediation (Lombard & Ditton, 1997) and/or non-simulation (Kukshinov, 2024), is not just any immersive state (Behm-Morawitz et al., 2016). Presence is a form of *sensory* immersion because it relies on the perceptual process, on sensory cues, or fidelity, i.e., on how well and coherently the simulation replicates some aspect of reality (Murphy & Skarbez, 2020). Something has to be simulated to be perceived. Otherwise, if it is not simulated, if it is not "there," it is left to the imagination as a possibility. Possibilities or uncertainty are beneficial for mental immersion as they stimulate the imagination, which is key to mental immersion.

Presence, as a sensory illusion, happens at the moment of perceiving the simulated, i.e., it is impossible to be immersed in VR by memory. For presence, this spatiotemporal sequence of sensory cues needs to be credible before it can be lived-in or experienced as real (O'Connor & Aardema, 2012). For *mental* immersion, it is the opposite. Mental immersion does not involve external simulation that is being perceived—it is based on the mental simulation, for instance, of narratives. Narrative, such as a book, a movie, or a song, is not a simulation that is perceived in which we may feel immersed—it is perceived to be mentally simulated. Narrative engagement can be described as a mental reconstruction of the narratives (Busselle & Bilandzic, 2009). The narrative unveils its structure in the imagination as it is only through this process that it attains credibility (O'Connor & Aardema, 2012). So, individuals need to live through narratives and engage emotionally to feel them as something meaningful. Also, mental immersion does not have to happen in the actual process of consuming a narrative—it can persist after consuming a narrative (Martínez, 2014). Along with technology, narratives do not inevitably immerse their consumers (who are not "users").

As a result, there are at least two types of immersion, i.e., sensory and mental, which can be represented by the states of presence and narrative engagement, respectively. A dual approach to immersion is most common in video game research. For instance, some researchers distinguished sensory and imaginative immersions or diegetic and situated immersions (as mentioned in Veale, 2012) or psychological and sensory/perceptual immersions (Carr et al., 2006). "Narrative" and "technological" conceptualizations of immersion are also common, but they focus on the potential source of the immersion, not on its cognitive nature as with "sensory"/"mental" conceptualization. Nilsson et al. (2016) also distinguished challenge-based immersion, which may arise from challenges to the user's motor or mental skills. However, this potential form of immersion seems to be very similar to the state of flow, as the authors themselves stated (Nilsson et al., 2016). In any case, based on the dual cognitive approach, the mental and sensory immersions are fundamentally different and, sometimes, contradict each other as they are based on different types of cognitive processing and forms of attention.

3.1. Storytelling and Narrative Issues

Such contradictions appear, for instance, when immersion into narratives impacts action possibilities, vection (i.e., perceived self-motion), reality judgment, and, consequently, presence (Balakrishnan & Sundar, 2011). Research also indicates that external factors, such as control over media content (Oh et al., 2014), can disrupt immersion into narratives (Busselle & Bilandzic, 2009). This happens because sensory immersion, or presence, which relies on active involvement and perception of external stimuli, can disrupt mental immersion, which is based on internal focus and mental simulations.

As a result, without differentiation of immersive experiences, presence scholars assume it is possible to feel presence "in" narratives. This may sound more plausible when researchers refer to audio-visual narratives, such as movies, because these types of narratives involve more sensory output. However, they are still narratives that need to be mentally processed for immersion to appear. When it comes to textual narratives, presence scholarship faces the so-called "book problem" (Gysbers et al., 2004; Schubert & Crusius, 2002). It is a problem because it becomes difficult for presence researchers to justify "presence in books" via sensorial terms, level of fidelity, and other associated factors. However, books and novels can be the most (mentally) immersive narratives as they engage imagination more than narratives represented via richer media modalities, such as movies (Green et al., 2008). Simultaneously, there is no research on "presence in cartoons" because presence researchers probably recognize this specific boundary. Overall, simulations can induce sensory immersive experiences, while narratives can induce mental immersive experiences. It is not correct to combine them, as narratives and simulations represent different types of media (Calleja, 2014).

The lack of this differentiation creates another assumption based on blurring the difference between presence and narrative engagement. This assumption implies a natural capability of "immersive" technologies to convey stories. However, this approach does not consider that storytelling, as a reproduction of narratives, can be immersive by itself, and that simulation technology does not improve but impedes storytelling. In short, "immersive" technologies do not allow users to follow the storyline once users have a choice of what to perceive. As a result, the simulative nature of "immersive" technologies impedes storyline comprehension (Pressgrove & Bowman, 2021), hindering recall of the story (Szita et al., 2018). However, story understanding and retention are pivotal for narrative engagement (Busselle & Bilandzic, 2009). As a result, regular flat screens, as media technologies, are better suited to consume narratives uninterruptedly and emotionally engage with them (Baños et al., 2004).

Video games are one of the most coherent examples of "immersive" or simulated storytelling (Gröppel-Wegener & Kidd, 2019) because they are designed as both simulations and narratives (Frasca, 2013). The story in video games is coded to progress depending on the players. There might be other examples of media, such as art installations, that make it possible to experience both sensory immersion from simulation and mental immersion into narratives.

3.2. Empathy, Perspective-Taking, and Identification Issues

There are more issues in video game research that stem from a lack of immersion differentiation. For instance, characters, as driving story elements (Eder, 2010), are often conflated with avatars (as in Downs et al., 2019), which are virtual representations of players in simulated environments (Nowak & Fox, 2018). This leads to mistaking character identification and avatar embodiment as the same concepts and experiences, even though they are distinct psychological processes. This further exemplifies the confusion between sensory (via avatar control) and mental experiences (via character relationships). However, when we imagine characters and their situations (even when we imagine ourselves with them), we cannot alter the course of events, as we do not control characters or possess any agency when we engage with narratives; characters also do not react to us, no matter how strongly we identify with them (Calleja, 2014). Those relationships are parasocial, or one-sided and imagined.

Arguably, because of this confusion, sometimes researchers assume that players identify with characters due to the fact of playing as them (as in Lin, 2013). However, identification requires mental effort—it is about an emotional connection with the character and the character's behaviour, motives, and desires (Busselle & Bilandzic, 2009). Characters, whether in books or video games, should be relatable, so that players can identify with them; it is not enough to play as them. Alternatively, embodiment is sometimes equated with the fact of using an avatar because, as sometimes suggested, the "body transfer" happens (Herrera et al., 2018; van Loon et al., 2018). However, embodiment does not simply happen when we use an avatar; it depends on the combination of various senses that are not always related to an avatar, such as a sense of location (Gonzalez-Franco & Peck, 2018).

In VR studies, in particular, the blurring of mental and sensory processes can become problematic. This happens because many VR researchers confuse the conception of a point of view (a sensory viewpoint) with a perspective of another person (a mental attitude and understanding of them), which produces an idea that VR is naturally capable of evoking perspective-taking just because we "see through the eyes of the other."

Perspective-taking is based on the mental effort to make inferences about and represent others' intentions, goals, and motives (Stietz et al., 2019), or feelings and thoughts of others in terms of affective and cognitive perspective-taking respectively (Healey & Grossman, 2018). Affective empathy is usually described as the ability to share the emotional experiences of others, while cognitive empathy is usually equated to affective perspective-taking (Cox et al., 2012; Healey & Grossman, 2018). These are mental processes of relating to and thinking about the other, which does not mean that the user of a technology becomes someone else. In any case, no matter how much time a person spends "in" a virtual body, it does not (necessarily) transform them; it is still the same person, who has certain attitudes and biases.

As a result, for instance, when a racist person is "placed" in the "body" of a person of colour, who is facing virtually simulated abuse, this (a) does not make them a different person with different experiences, and (b) does not automatically make them less racist due to this intervention. Instead, users of these technologies remain themselves, along with any stereotypes and biases these individuals may have. If there are any biases attributed to certain simulated identities, then they are reproduced in such situations. This effect is called the Proteus effect (Yee & Bailenson, 2007). So, the question is not whether these technologies help to reduce biases, but rather how much reproducing these expressions of biases and stereotypes reinforces the biases by reliving and practising them in the virtual settings.

In addition to that, the whole premise of this type of research is problematic as it promotes identity tourism (Nakamura, 2013), a form of "superficial, reversible, recreational play at otherness…[based on] an episodic experience" (p. 55). What generally happens in such studies is a reduction of the human lives and tragedies into the virtually visualized pieces of information posed as "real experiences." As Nakamura (2013) discusses further, this glimpsing at other people's lives does not entail any real consequences or impact for users:

> In cyberspace, players do not ever need to look for jobs or housing, compete for classroom attention, or ask for raises. This ensures that identity tourists need never encounter situations in which exotic otherness could be a liability….Players who represent as members of a minority may get the impression that minorities "don't have it all that bad," since they are unlikely to find themselves discriminated

> against in concrete, material ways. This imperfect understanding of the specific "real life" social context of otherness can lead to a type of complacency backed up by the seemingly unassailable evidence of "personal experience." (pp. 56–57)

As a result, such studies are not only incorrect in their underlying assumptions—they can also be dangerous in regard to the effects they have on the participants by deepening the ignorance towards traditionally marginalized groups.

4. Discussion and Conclusion

"Immersive technology" is neither a useful nor a precise term. It reflects a technologically deterministic (and marketing-driven) framework that is currently dominant in the scholarship. Technology use is not equal to any particular psychological state, including immersion or immersive experiences. At the same time, scholarship and forms of immersive experience are not bounded by certain technologies—immersion is a complex and diverse psychological state. Simulation technology can induce sensory immersion or presence by presenting a coherent set of sensory cues. Narratives can induce mental immersion by mentally simulating narrative possibilities. In other words, there are different forms of immersion, and they often contradict each other. The relationship between the different types of immersions can be tested using mixed methods, especially if questionnaires, such as presence questionnaires, are context-dependent (Kukshinov et al., 2024) and require clarifications from the questionnaire respondents. Phenomenological analysis may be the best way to examine different immersive experiences in detail.

Even though sensory and mental immersions may contradict each other, their combination through "immersive" or rather virtually simulated storytelling is possible. Video games are a great example of combining narratives and simulations. Still, there is a necessity to maintain a constant balance between the focus on the simulation and engagement with narratives, or players' agency and characters' relationships.

Alternatively, documentaries can be a better content to represent via simulation technologies. It is possible to minimize the impact of the simulation by "reducing" the narrative structure of the content. In other words, more informative and less fictional content can be better suited for virtual and simulation technologies, as it is less immersive, or, in other words, extractive (Kukshinov, 2023), which refers to information as media content (Humphreys et al., 2013).

In addition, it may be possible to assign different modalities for the simulation and narrative parts. In particular, it can be useful to use the audio channel for the narrative and the video channel for the simulation (i.e., a 360-degree video). As a result, it would be possible to visually stimulate a sense of space through a simulation and provide a mentally engaging audio-recorded narrative. This way, the story is not intervened by the sensorial input—it is rather supplemented.

Even though simulation technologies are not naturally designed to tell stories, these technologies are very impactful and useful in certain areas that require stimulating senses/sensations or vividly informing users via sensory immersion or presence. These technologies are effective in simulating situations to train and stimulate learning (Grassini et al., 2020) or to prepare for new circumstances (Lanzieri et al., 2020). VR is extremely useful, for example, in terms of VR exposure therapy, when it is necessary to simulate virtual contexts that are perceived as less intimidating than real ones to treat phobias (Price & Anderson, 2007). In the end, simulation itself and control over simulation can be fun and entertaining (Grodal, 2000).

Simulation technologies may not make stories more involving, or people less racist, but these technologies are still incredibly impactful in their own way. It is necessary to understand the boundaries and use the benefits of these technologies to the fullest extent. It is also crucial to remember that it is the processing of these technologies that can have an effect on their users, not the mere fact of using them. Moving forward, it is imperative to refine our understanding of immersion beyond technological determinism and a unified conceptual framework. By embracing this, we can harness the transformative potential of the simulation technologies while addressing critical questions about their societal, ethical, and psychological implications.

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Conflict of Interests

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ARTICLE

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The Stigma Machine: A Study of the Prosocial Impact of Immersive VR Narratives on Youth in Spain and Canada

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Abstract

Virtual reality (VR) is increasingly employed to create immersive, interactive audiovisual narratives that accentuate emotion, storytelling, and user engagement. By harnessing the potential of VR, these avant-garde narratives aim to instill values of equity, justice, and fairness. This article critically examines the largely unsubstantiated assertion that VR is the ultimate tool for fostering empathy by means of a qualitative evaluation of the influence of prosocial VR audiovisual narratives. The study involved the production of the first episode of *The Stigma Machine*, a VR short film series in both traditional 2D and immersive VR formats, in a two-pronged production approach designed to examine the effects of the film on a sample of 44 university students from Spain ($n = 22$) and Canada ($n = 22$). The participants were segregated into two groups: Group 1 (1st VR Condition) viewed the VR experience first, followed by the traditional version, while Group 2 (1st Video Condition) viewed the two formats in reverse order. Data was collected before, during, and after viewing, using standardized questionnaires (interpersonal reactivity index, basic empathy scale, and Igroup presence questionnaire) and electroencephalogram devices to monitor brain activity. The dependent variables included: empathy, assessed using the interpersonal reactivity index and basic empathy scale surveys; electroencephalogram brain activity measures, indicating engagement, excitement, focus, interest, relaxation, and stress; presence, evaluated using the Igroup presence questionnaire; and various outcome variables. The results reveal no significant differences in presence and no significant changes to the empathy scores. The findings point to a need to focus more on narrative design and audiovisual content creation strategies than on VR technology itself.

Keywords

electroencephalogram; immersive narratives; prosocial impact; virtual reality; VR short film

1. Introduction

Extended reality technology enables users to interact with immersive stories and environments. The use of virtual reality (VR), mixed reality, and augmented reality technology has increased dramatically in recent years due to the buzz surrounding the Metaverse. Though research on VR has focused mainly on video games, there is a burgeoning interest in the use of these technologies as prosocial instruments, with the creation and assessment of immersive VR experiences designed to elicit positive social behavior. A substantial body of research has examined the impact of VR experiences as tools for eliciting positive social outcomes (Canet & Sánchez-Castillo, 2024; Martínez-Cano et al., 2023; Nikolaou et al., 2022; Tassinari et al., 2022). VR devices are also becoming increasingly affordable, opening up the possibility of "a full integration of VR technology with movies, which is progressively leading to a significant advancement in traditional screen cinema" (Tian et al., 2022, p. 1).

Immersive media make it feasible to place users in scenarios and settings that could be hard to reproduce in the real world. VR enhances the audience-storyteller relationship by empowering users to participate actively in the narrative they are witnessing, placing them inside the story, and giving them a sense of presence (Lombard & Ditton, 1997). Place illusion is one of the keys to achieving this sensation of "being there," as "it helps to create the effect of presence" (Martínez-Cano et al., 2023, p. 3).

Immersive audiovisual content may therefore foster positive attitudes and emotions such as empathy, compassion, and teamwork, justifying Milk's (2015) description of VR as the "ultimate empathy machine." Such content can provide users with the opportunity to adopt the perspective of another person, in so-called "perspective-taking" experiences (Herrera et al., 2018) or social modeling activities, in which they observe and imitate the actions of others in a VR setting, leading to embodiment.

According to Barsalou's (2008) theory of grounded cognition, our ideas and behaviors are shaped by our physical experiences, which include interacting with others and our surroundings. Because VR is so engrossing, users may experience a sense of presence in a VR environment. This experience can influence the user's beliefs, attitudes, actions, and social interactions. An embodied experience in a VR environment can exert considerable influence over various cognitive and emotional mechanisms. For instance, VR simulations of physical activity, such as walking, can improve cognitive functioning among elderly individuals (Riva et al., 2007). Similarly, VR scenarios depicting intergroup encounters have been harnessed to promote prosociality by encouraging empathetic responses while reducing stress and prejudicial attitudes (Banakou et al., 2016; Gonzalez-Franco et al., 2016; Stelzmann et al., 2021; Tassinari et al., 2022).

In opposition to these arguments, Robertson (2017) questions Milk's description of VR as an empathy machine based on the lack of empirical evidence to support the assertion. Moreover, research on the psychology of immersive experiences suggests that users may occasionally find it challenging to handle the many inputs of immersive content effectively (Bowman, 2021), which may undermine their emotional responses to the stories or have the effect of distancing them from the characters (Barreda-Ángeles et al., 2021). Some studies also suggest that VR may encourage "false empathy," contradicting the idea that first-hand accounts and immersive experiences alone can elicit empathy (Bender & Broderick, 2021; Bloom, 2017). Based on such criticisms, Lisa Nakamura (2020) argues that VR empathy experiences encourage a kind of "identity tourism," whereby a VR user pretends to be a member of a marginalized group or to share a group experience, usually for voyeuristic purposes. This results in false embodiment, in the sense of occupying an identity completely different from our own, which in turn leads to false empathy (Nakamura, 2020).

1.1. The Impact of Immersive VR Narratives vs. Traditional Media Formats

In one of the various studies that have compared the effectiveness of VR and linear 2D screen formats, Barreda‐Ángeles et al. (2020) measured the impact of 360° nonfiction content in both immersive head‐mounted display and non‐immersive 2D screen formats, exposing half of the participants first to four VR videos followed by four videos presented on screen, and the other half with the opposite order of media exposure. They found that the immersive content had no notable impact on empathy, possibly due to a potential offsetting mechanism between indirect positive and direct negative effects. This constitutes a case of "competitive mediation," suggesting that immersive presentations may elicit reactions from viewers related more to their personal immersive adventure than to spatial presence or the events depicted, thus hindering empathy and emotional engagement. While enjoyment negatively mediated the spatial presence effect on the empathic concern dimension, no negative effect was found for perspective‐taking (Barreda‐Ángeles et al., 2020, p. 686).

Research conducted by Zhang et al. (2020, p. 6) concluded that VR gives its audience a variety of aesthetic experiences through its immersiveness, real‐time interactivity, and user conception, and that the various aesthetic sensations produced by VR visuals challenge the conventional definition of what constitutes good visual design, as virtual experiences and content are starting to take on a personality of their own. Based on this perception, a study by Szita et al. (2018) hypothesized that highly immersive experiences may impact information intake and how storytelling events are understood. Some years earlier, Mateer (2017) was already arguing that although VR content could be impressive and convincing, thereby enhancing the immersive experience, it is important to take into account viewers' point of view, position, body, and agency of movement, as these elements may affect their access to narrative content. In their research, Szita et al. (2018, p. 414) used two versions (VR and screen formats) of the same animated short film, *Pearl* (Osborne, 2016), as independent variables to examine "whether cinematic virtual reality and screen‐based viewing would evoke different experiences in terms of engagement, presence, emotions, memory characteristics, and recollection accuracy." When they used VR headsets to watch the movie, participants exhibited a higher level of engagement with the film and a decreased awareness of the outside world. They also reported experiencing a heightened sense of immersion within the narrative's fictional environment compared to participants viewing the content on traditional screens. At the same time, there were no appreciable differences in emotional engagement with or empathy for characters between 2D screen and VR viewers. Conversely, Carpio et al. (2023) compared the emotional and cognitive impacts of VR and traditional screen formats on a sample of 60 participants, in a multimodal experiment where one group watched the movie *Gala* (Carpio, 2022) in VR and the other group viewed it in 2D, concluding that the VR movie had a substantially stronger effect on viewer emotions and elicited higher levels of immersion and engagement than the 2D version. The study combined self‐reports and questionnaires—the positive and negative affect schedule and the self‐assessment manikin—with heart rate variability and electroencephalogram (EEG) brain activity data, thereby confirming "the value of using a multidisciplinary method for analyzing audience impacts" (Carpio et al., 2023, p. 3188).

Ding et al. (2018) also compared traditional 2D films with VR in terms of their emotional effects, with a sample of 40 participants separated into two groups, VR and 2D, both shown the same content: *The Jungle*

Book (Reitherman, 1967). None of the participants had prior experience with VR. The study used positive and negative affect schedule, skin temperature, electrocardiogram, respiration signal, and photoplethysmography measures. The results indicated a more pronounced emotional impact among VR viewers than 2D viewers, corroborating Riva's findings that "confirmed the efficacy of VR as an affective medium in eliciting specific emotions of anxiety and relaxation" (Riva, 2007, as cited in Ding et al., 2018, p. 9). A study by Tian et al. (2022) sought to determine whether the variance in emotional arousal between 2D and VR stimuli consistently manifests as statistically significant by testing a sample of 16 participants using different questionnaires (self-rating anxiety scale, self-rating depression scale, self-assessment manikin) combined with EEG-based trials. The researchers developed a series of virtual scenarios designed to elicit positive, negative, or neutral emotions, and participants were separated into two groups: one viewing the scenarios in VR and the other viewing them in 2D. The study found that VR environments "can trigger increased emotional arousal" (Tian et al., 2022, p. 13). On the other hand, a study by Wang et al. (2018) that examined the power of 360-degree VR news videos for enhancing engagement demonstrated that VR videos exhibited inferior performance compared to 2D screen videos. This study did not test any particular content on users; instead, a series of data analyses were conducted based on popularity indicators on a sample of content that included 299 VR videos and 299 screen-based videos produced since 2015.

1.2. Objectives and Hypothesis

Clearly, more research is needed to explore the differences between VR and 2D screen narratives in terms of their effects on viewers. While some studies assert that immersive narratives foster a stronger emotional bond with narrative content than a traditional linear format, others conclude the opposite. Some make optimistic claims about the potential benefits and trade-offs for the user's social and ethical awareness. To fill the research gap in this area, this study proposes an experimental design that integrates a range of approaches used in earlier research in an effort to compare the prosocial impact of the two media formats.

In view of the above considerations, this study postulates the following hypothesis: Exposure to immersive VR prosocial audiovisual narratives will have a greater impact on fostering empathy, engagement, and positive emotional responses in viewers compared to traditional 2D screen formats. This hypothesis will be tested by comparing the cognitive and emotional responses of participants who view the same narrative in both VR and 2D screen formats.

2. Methodology

2.1. Design

This study used a pre/during/post design. Participants were exposed to both versions of the stimuli but were divided into two groups: Group 1, or 1st VR Condition, watched the VR film stimulus first and the video format of the film second; and Group 2, or 1st Video Condition, watched the traditional video content first and the VR stimuli second. A within-subjects design, frequently used in media psychology research, was employed to investigate whether immersive VR and screen viewing evoke different responses in terms of empathy, sense of presence, and emotional involvement. This design was chosen primarily due to the need to control for individual variability of the results, thereby reducing the likelihood of genuine differences between conditions going undetected or being obscured by random fluctuations. Moreover, within-subjects designs can use smaller sample sizes to identify statistically significant differences between two conditions. The independent variable was the viewing order condition, determined by the format that was viewed first (2D screen or VR). The stimuli were two iterations of the same movie and there were two subconditions—the “initial” (basal) and “boo” (post) moments—that corresponded to two distinct points in the story where EEG brain activity data was collected while participants were viewing the stimuli in VR and screen-based formats.

2.2. Film Stimulus

In order to study the prosocial impact of VR immersive narratives compared to traditional linear 2D screen content, we produced the first episode of a VR short film series titled *The Stigma Machine* (Martínez-Cano, 2022) in both formats (Figure 1). *The Stigma Machine* is an experimental VR story that attempts to put the spectator into another person’s shoes while addressing the issue of social stigma. The aim is to use this technology as a prosocial input to encourage supportive behaviors in relation to sensitive topics in today’s society, such as respect and tolerance for the diversity of the LGBTIQA+ community. The first episode is a hybrid immersive movie created for VR devices, produced by combining volumetric filmmaking and 3D CGI, with a duration of 2 minutes and 30 seconds.

Volumetric video capture is a growing trend in immersive content production (augmented reality/VR/mixed reality). It provides VR experiences based primarily on 3D scanned images taken by depth sensors such as Microsoft Azure or Kinect 2. With the help of gaming engines such as UDK and Unity, the technologies of photogrammetry and volumetric video allow the viewer to enter realistic virtual worlds that are recreated by combining artificial 3D elements with real actions captured in volumetric video format (Figure 2). A Microsoft Kinect 2 sensor and 3D reconstruction of the areas and objects that serve as the story’s settings were used to create this first episode. The resulting non-interactive, immersive audiovisual experience can be described as having two layers, as the sets for the action were reconstructed in 3D CGI, while the actors’ performances were captured on film sets with chroma backgrounds using volumetric video recording with 4k DSLR cameras, Kinect sensors, and Depthkit software. The sound production for the stimulus was captured for both formats using a stereo system display and subsequently edited to create an immersive auditory experience for the VR format. This was achieved by means of spatial sound design, which enables users to perceive sound more realistically based on their distance and spatial position relative to the observer.

The film tells the story of a student who is bullied in a classroom because of their gender identity. Over the course of two days, the actors’ performances were filmed on a set using a chroma background (Figure 3). Since

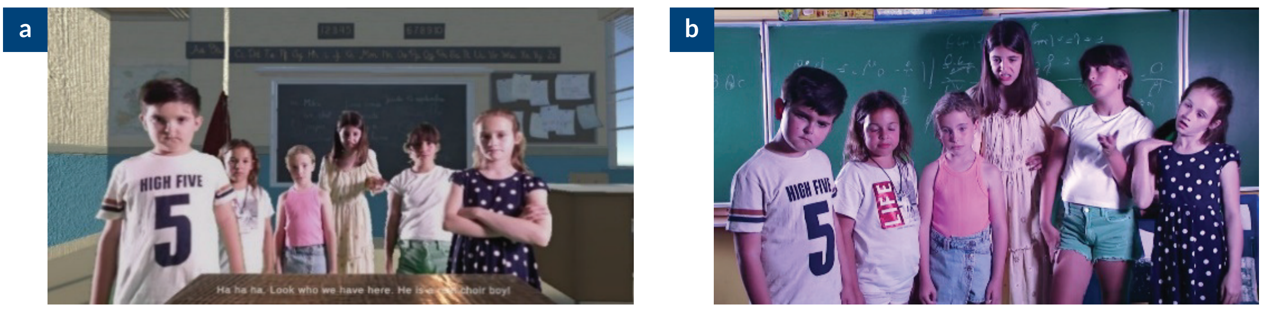

Figure 1. Screenshots of the film stimuli in VR format (a) and in video format (b). Source: Martínez-Cano (2022).

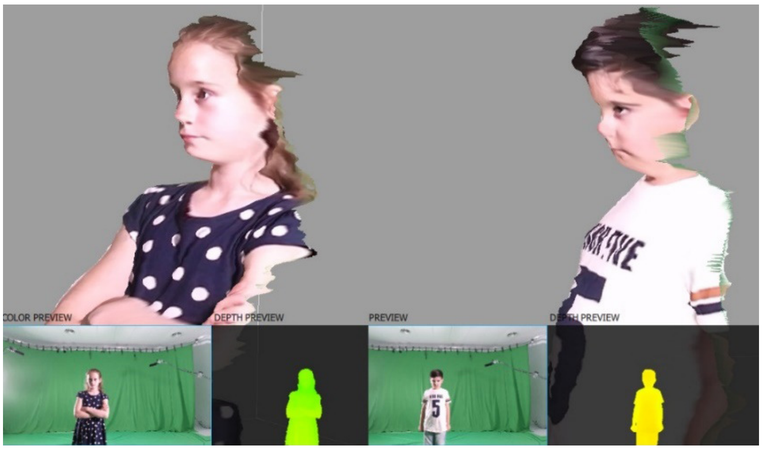

Figure 2. Screenshot during the volumetric video recording using Depthkit software.

Figure 3. Shooting process for the VR experience *The Stigma Machine*.

the furniture and props were made later and added in 3D, they did not need to be built for the scene. Autodesk Maya was used to create the classroom set, which the user can visually explore as the narrative progresses. In order to be able to insert each actor into the virtual setting later and to create the ideal composition for communicating the intended message to the audience, the performances were first recorded with the entire group and then with each actor separately. The sensor was placed at the user's eye level so that it was in the same position as the child who was being bullied by his peers during the story. Afterward, the group recording was edited for the conventional linear screen-based version of the short film. There are two specific events in the storyline: the "initial" point where one of the girls starts to yell at the viewer (who is in the position of the main character in a sort of perspective-taking narrative strategy); and a second moment near the end where the kids jeer at the spectator (the "boo" subcondition). Since both formats follow the same script, there is no difference in storytelling between the immersive and non-immersive modes. The film was shot in Spanish and subtitled in English.

2.3. Participants

Initially, 50 young university students from Spain (n = 23) and Canada (n = 27) took part in the study. Six participants were removed from the sample at the end of the experiment either because they did not complete all phases of the experimental design or because the signal used to record their brain activity while viewing was of insufficient quality to measure the various research variables. The final sample thus included 44 participants, 22 from each country. A total of 88.2% of the participants were between 18 and 25 years old, 7.8% were between 25 and 30 years old, and 3.9% were older than 30. Participants were recruited through online advertisements and by word of mouth at two universities: Toronto Metropolitan University and Universidad Miguel Hernández de Elche. Participants received no compensation apart from a five-dollar voucher for a coffee shop franchise. The study forms part of the research project titled The Role of Virtual Reality Audiovisual Narratives in Social Inclusion and the Perspective of Prosocial Models: Analysis of Their Characteristics, Effects and Impact on Young University Students, which was reviewed and approved by the Toronto Metropolitan University Research Ethics Board (REB 2022–376) and by the Miguel Hernández University Research Ethics Board (DCS.FMC.01.21).

2.4. Apparatus, Setup, and Procedure

The participants were invited to attend the lab installed at The Catalyst at Toronto Metropolitan University and at the Atzavares building at Universidad Miguel Hernández de Elche, where the two conditions were set up in a neutral environment. For the 1st VR Condition ($n = 19$), participants viewed the VR version of the short film first using an OCULUS Rift S device, while for the 1st Video Condition ($n = 25$) participants watched the 2D format film first on a 17-inch screen laptop.

Data was collected before, during, and after the viewing stages. On their arrival at the lab (pre-viewing stage), participants were asked to fill out two online questionnaires: Form 00 with demographic data; and Form 01, which included the interpersonal reactivity index (IRI; Davis, 1980, 1983) and the basic empathy scale (BES; Jolliffe & Farrington, 2006). Subsequently, participants in both conditions watched the two versions of the short film in the order assigned to their group, and their brain activity was recorded during both viewings using an EMOTIV EPOC X EEG device. Stimulus exposure in both formats lasted 2 minutes and 30 seconds, with a 5-minute break between each exposure. After viewing, participants were asked to complete online Form 01 (IRI and BES) again, as well as Form 02 (outcome variables) and Form 03, which included the Igroup presence questionnaire (IPQ; Schubert et al., 2001). At the end of the study, participants were debriefed. Including the instructions, viewing the two formats, and completing the pre- and post-viewing surveys, the entire procedure took about 30 minutes.

2.5. Measures

Participants were asked to answer a set of pre-viewing and post-viewing surveys that included standardized questionnaires (IRI, BES, and IPQ). The internal consistency of these questionnaires in our study was moderate, with Cronbach's alpha values ranging between 0.5 and 0.7. The outcome variables survey was specifically created for this study. Additionally, while the participants were viewing both formats, an EEG device was used to monitor brain activity. The measures taken were as follows.

The dimensions of empathy were assessed using the IRI and BES surveys. The IRI measures were obtained based on Table 6 in Pérez-Albéniz et al. (2003). Perspective-taking was measured based on items 3, 8, 11, 15, 21, 25, and 28; fantasy based on items 1, 5, 7, 12, 16, 23, and 26; empathic concern based on items 2, 4, 9, 13, 14, 18, 20, and 22; and personal distress based on items 6, 10, 17, 19, 24, and 27. The BES was calculated using the authors' guidelines (Jolliffe & Farrington, 2006). The cognitive BES variable was obtained by adding the scores of items 3, 6, 9, 10, 12, 14, 16, 19, and 20 of the BES questionnaire. Affective BES was calculated by adding the scores of items 1, 2, 4, 5, 7, 8, 11, 13, 15, 17, and 18 of the BES questionnaire, and the BES total score was obtained by adding up all the scores of the items of the BES questionnaire, i.e., the sum of the scores of items 1 to 20.

EEG brain activity measures were captured using an EMOTIV EPOC X device. Recordings were made using 14-channel electrodes, continuously recorded at a sampling frequency of 1,000 Hz. Engagement, excitement, focus, interest, relaxation, and stress were measured using the EmotivPro software performance metrics during the "initial" (basal) and "boo" (post) subconditions. Performance metrics are recorded on a scale from 0 to 100. Engagement is characterized by alertness and the conscious focus on task-relevant stimuli, measuring the degree of immersion, which combines attention and concentration. Excitement reflects positive physiological arousal, indicated by activation of the sympathetic nervous system, and it provides output scores showing short-term changes in excitement, even within seconds. Focus measures the intensity of attention on a single task. Interest measures the level of attraction or aversion to the stimuli, environment, or activity. Relaxation measures the ability to disengage and recover from intense concentration. Stress indicates the comfort level with a stimulus.

Presence was measured using the IPQ questionnaire (Schubert et al., 2001). The variable of spatial presence was calculated by adding the scores of items 3, 6, 9, 10, and 13 of this questionnaire. Involvement was determined by adding the scores of items 1, 7, 11, and 14, and experienced realism was calculated by adding the scores of items 2, 4, 5, and 12. The general score was obtained by adding the scores of item 8.

Regarding outcome variables, a combination of different types of questions and prompts were used in order to assess the VR experience. The first was a "yes or no" question: Did you feel comfortable with the interactive systems proposed? To measure the level of emotional involvement, we used a 9-point Likert scale adapted from Batson et al. (1997), asking participants to rate the extent to which they felt moved, sympathetic, and/or compassionate. To measure negative emotional response, we added a 9-point Likert scale adapted from Batson et al. (1997), asking participants to rate the extent to which they felt uncomfortable, worried, anxious, or upset. To measure social presence, we used two 5-point Likert scales based on the social presence scale (Nowak & Biocca, 2003), asking participants to rate how strongly they felt that characters were present and how strongly they felt that characters were aware of their presence. To measure the participants' relationship of "otherness" with the main character, we used the inclusion of the other in the self scale (Aron et al., 1992), utilized predominantly in social science research to assess social connectedness. This scale has a valence score range from 1 to 7 (Figure 4), whereby a higher number indicates a stronger connection with the main character of the story. These results were split into four ranks: 1; 2 to 3; 4 to 5; and 6 to 7. Participants responded to the prompt: "Please select the image number (in red) that best describes your relationship with the main character of the narrative you have seen." We also used three 5-point Likert scale prompts to measure participants' degree of comfort with the first-person narrative perspective, with diverse sexual orientation kissing, and with collaborating with team members of a different race or sexual orientation. Finally, to assess the image quality of the VR experience, we added two questions with the following single-answer options: sublime, marvelous, strange, beautiful, realistic, confusing, artificial, impressive, surrealistic, and other. The two questions were "what do you think of the image quality of the classroom in this VR?" and "what do you think of the image quality of the children in this VR?"

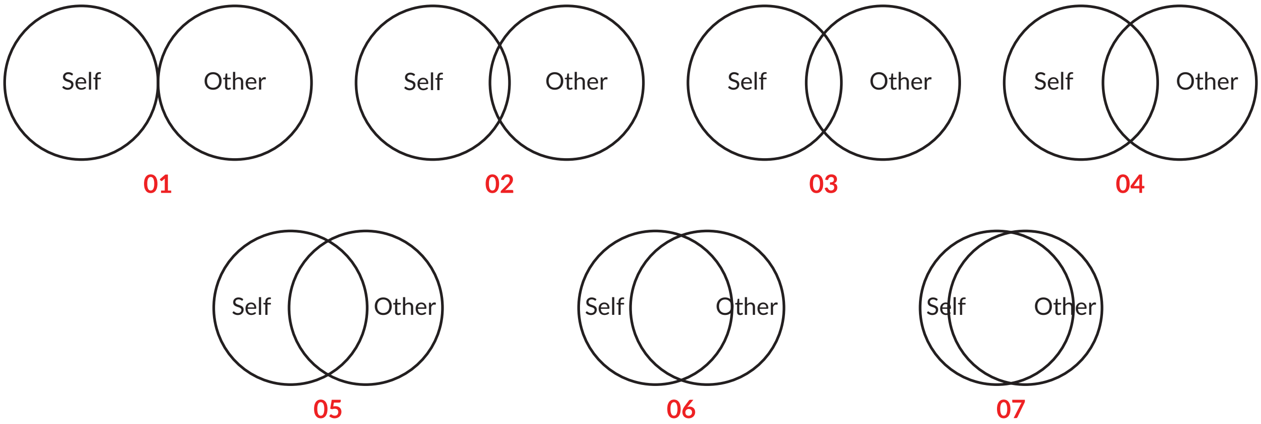

Figure 4. The inclusion of other in the self scale, a unidimensional visual instrument for assessing social connectedness. Source: Aron et al. (1992).

2.6. Statistical Analysis

The statistical analysis was performed using R software version 4.2.0 (R Foundation for Statistical Computing, Vienna, Austria; http://www.R-project.org). All statistical tests were bilateral, and the significance level was established at 0.05. Before conducting the analysis, we checked whether the continuous variables followed a normal distribution by applying the Kolmogorov-Smirnov test.

Variables that follow a normal distribution are described using means and standard deviations, while those that do not are analyzed using medians and interquartile ranges. On the other hand, qualitative variables are described using frequency (n) and percentage (%). To compare quantitative variables across intervention groups, the Student's t-test for independent samples was used for normally distributed variables, or the Mann-Whitney U test for non-normally distributed variables. For qualitative variables, the Fisher's exact test was used with two categories, and the Chi-square test was used for variables with more than two categories.

To evaluate quantitative variables before and after the intervention, the Student's t-test for paired samples was used for normally distributed variables, and the Wilcoxon test for non-normally distributed variables. Finally, to analyze changes in quantitative variables between intervention groups, the Student's t-test was used for normally distributed variables, and the Mann-Whitney U test was used for non-normally distributed variables. In addition, effect sizes were determined using Cohen's d for variables with normal distribution and Cliff's Delta for variables without normal distribution. Effect sizes can be classified as small, medium, or large based on Cohen's d values of 0.20, 0.50, and 0.80, and Cliff's Delta values of 0.147, 0.330, and 0.474, respectively.

3. Results

The sample included 44 participants, 19 of whom viewed the short film in VR first, while the other 25 viewed it first on a 2D screen. Table 1 shows the participants' sociodemographic characteristics both for the total and broken down by viewing group. Fifty percent of participants were ≤ 25 years old, 50% were from Spain, and the other 50% were from Canada. A total of 68.2% had previous experience with VR audiovisual content but only 6.8% considered themselves regular users of VR headsets, while 63.6% reported that they were regular video game players and 70.5% preferred viewing fictional audiovisual content. Most participants (86.4%) had

Table 1. Participant characteristics overall and broken down by group (1st VR and 1st Video).

	Total (n = 44)	1st VR (n = 19)	1st Video (n = 25)	p-value
Age				0.761
≤ 25y	50% (22)	52.6% (10)	48% (12)	
> 25y	50% (22)	47.4% (9)	52% (13)	
Country				0.761
Spain	50% (22)	52.6% (10)	48% (12)	
Canada	50% (22)	47.4% (9)	52% (13)	
Do you have experience with VR audiovisual content?				0.495
Yes	68.2% (30)	73.7% (14)	64% (16)	
No	31.8% (14)	26.3% (5)	36% (9)	
Do you consider yourself a regular user of VR headsets?				0.721
Yes	6.8% (3)	5.3% (1)	8% (2)	
No	93.2% (41)	94.7% (18)	92% (23)	
Do you play video games regularly?				0.565
Yes	63.6% (28)	68.4% (13)	60% (15)	
No	36.4% (16)	31.6% (6)	40% (10)	
What type of audiovisual content do you prefer?				0.797
Fiction	70.5% (31)	68.4% (13)	72% (18)	
Non-Fiction	29.5% (13)	31.6% (6)	28% (7)	
Are you a volunteer for a pro-social NGO or charity?				0.378
Yes	13.6% (6)	21.1% (4)	8% (2)	
No	86.4% (38)	78.9% (15)	92% (23)	
Do you consider yourself an active participant in improving your community?				0.900
Yes	43.2% (19)	42.1% (8)	44% (11)	
No	56.8% (25)	57.9% (11)	56% (14)	

Note: p-value estimated from the Fisher's Exact Test or Chi-square test.

never volunteered with any NGO, although 43.2% considered themselves to be actively involved in improving their community. A comparison of the audiovisual content and sociodemographic characteristics between the two groups found no significant differences.

Table 2 shows the data for each group at the two key points of the storyline, i.e., the "initial" (basal) and "boo" (post) subconditions. No changes were observed between basal and post moments of the short film for IRI or BES for either the group that viewed the VR movie first or the group that watched the video first. On the other hand, a decrease in EEG parameter scores was observed when viewing the VR film in the group that watched the video first, while no significant changes were observed in the group that viewed the VR first. When viewing the video, a significant decrease in the engagement and relaxation scores was observed in both groups. Moreover, the group that viewed the VR version first also experienced a significant decrease in

Table 2. Description of IRI, BES, EEG in VR, and EEG in video between basal and post moments for each study group (1st VR and 1st Video).

	1st VR (n = 19)			1st Video (n = 25)		
	Basal	Post	p-value	Basal	Post	p-value
IRI, median (IR)						
Perspective taking	19 (16; 23.5)	19 (17; 22.5)	0.334	20 (18; 22)	20 (17; 22)	0.633
Fantasy	18 (16.5; 20)	19 (16.5; 21)	0.061	22 (19; 23)	21 (17; 24)	0.572
Empathetic concern	21 (17; 24.5)	21.5 (18.3; 26.8)	0.173	22 (20; 25)	24 (19; 27)	0.053
Personal distress	10 (8.0; 14)	10 (8.5; 16)	0.701	13.5 (10.8; 15.3)	15 (10; 16)	0.955
BES, mean (*SD*)						
Cognitive	30.3 (3.5)	30.9 (3.8)	0.459	32 (3.1)	31.7 (4.2)	0.633
Affective	33.5 (7.3)	34.4 (7.4)	0.148	35.5 (4.9)	36.8 (6.2)	0.080
Total	64 (9.6)	65.3 (8.7)	0.207	67.4 (6.4)	68.5 (9.2)	0.353
EEG in VR, median (IR)						
Engagement	74 (65; 91)	72 (63.5; 81)	0.052	71 (66; 73)	64 (57; 67)	0.001
Excitement	23 (16; 45.5)	25 (13.5; 32.5)	0.314	39 (24; 46)	20 (16; 28)	< 0.001
Focus	37 (25; 42.5)	34 (28.5; 38)	1.000	43 (33; 50)	35 (26; 39)	< 0.001
Interest	45 (42; 50)	44 (42.5; 49.5)	0.586	50 (48; 64)	44 (41; 49)	< 0.001
Relaxation	32 (28.5; 42)	32 (28.5; 42)	0.266	45 (32; 66)	35 (22; 59)	0.004
Stress	35 (33; 39)	36 (33.5; 44)	0.218	43 (35; 68)	35 (34; 41)	0.003
EEG in Video, median (IR)						
Engagement	71.0 (65.5; 80.5)	65.0 (61.0; 70.5)	< 0.001	87.0 (73.0; 84.0)	67.0 (63.0; 73.0)	< 0.001
Excitement	17.0 (11.0; 36.0)	13.0 (6.0; 18.0)	0.003	24.0 (10.0; 40.0)	20.0 (12.0; 32.0)	0.882
Focus	38.0 (29.5; 43.0)	31.0 (24.0; 33.0)	0.004	33.0 (24.0; 36.0)	34.0 (26.0; 41.0)	0.241
Interest	48.0 (43.0; 53.0)	43.0 (38.5; 48.5)	0.042	51.0 (45.0; 60.0)	47.0 (41.0; 53.0)	0.065
Relaxation	37.0 (25.5; 55.5)	20.0 (17.0; 37.5)	0.031	52.0 (35.0; 64.0)	31.0 (23.0; 47.0)	0.007
Stress	36.0 (32.5; 58.5)	34.0 (29.0; 37.5)	0.098	40.0 (34.0; 59.0)	35.0 (32.0; 39.0)	0.288

Notes: IR = interquartile range; p-value obtained from paired t-students (parametric) and paired Wilcoxon (non-parametric).

the excitement, focus, and interest scores between the two key points of the storyline while viewing the film in video format. A drop in excitement, focus, and interest scores was also observed during VR viewing in the group that viewed the short film in video format first.

The drop in engagement between the two key moments while viewing the VR film was greater in the group that watched the video first. Participants who viewed the video version first also had a higher initial engagement when viewing the video, while the group that viewed the VR version first showed no significant variation in engagement levels while viewing the immersive narrative, and only a slightly bigger drop between the two key moments of the story when viewing the video format, although the engagement levels in both formats were fairly regular for this group.

Table 3 presents the changes to the results for IRI, BES, EEG in VR, and EEG in the video between the basal and post moments for both groups. Significant differences were observed between the two groups in the changes to the parameters of focus, interest, and stress while viewing the VR version, as the group that viewed the video format first experienced an 11-point drop in focus, while in the group that viewed the VR version first this parameter decreased by only one point. The 1st Video Group also experienced a 16-point drop in excitement and a 10-point drop in interest while viewing the VR version, compared to much smaller decreases for these parameters in the group that viewed the VR format first (−1 and −2, respectively). In addition, an eight-point decrease in stress was observed in the 1st Video Group while viewing the VR version, while the 1st VR Group experienced a two-point increase for this parameter. On the other hand, while viewing the video version, significant differences were observed between the two groups in the changes to excitement

Table 3. Differences in IRI, BES, EEG in VR, and EEG in video between basal and post moments for each study group (1st VR and 1st Video).

	1st VR (*n* = 19)	1st Video (*n* = 25)	*p*-value	Effect sizes
	Post-Basal	Post-Basal		
IRI, median (IR)				
Perspective taking	1 (−1.5; 2.0)	0 (−2.0; 1)	0.250	0.204
Fantasy	1 (0.0; 2.5)	0 (−2.0; 2)	0.109	0.287
Empathic concern	0.5 (−0.8; 2.0)	1 (−1.0; 3)	0.709	−0.069
Personal distress	0 (−1.0; 1.0)	0 (−2.0; 1.3)	0.643	0.086
BES, mean (*SD*)				
Cognitive	0.5 (3.1)	−0.3 (2.9)	0.371	0.280
Affective	0.9 (2.6)	1.3 (3.6)	0.666	−0.132
Total	1.4 (4.5)	1 (5.5)	0.826	0.068
EEG in VR, median (IR)				
Engagement	−3 (−12; 0.5)	−7 (−11; 0)	0.448	0.137
Excitement	−1 (−24.5; 6.5)	−16 (−26; −6)	0.072	0.322
Focus	−1 (−3.5; 11)	−11 (−19; −3)	0.013	0.422
Interest	−2 (−4; 2.5)	−10 (−12; −1)	0.003	0.539
Relaxation	−2 (−11; 6.5)	−9 (−20; −3)	0.104	0.291
Stress	2 (−2; 8)	−8 (−26; 0)	0.002	0.568
EEG in video, median (IR)				
Engagement	−5 (−14.5; 0)	−8 (−15; −3)	0.245	0.208
Excitement	−8 (−19; −4.5)	2 (−8; 8)	0.031	−0.385
Focus	−6 (−10.5; 0)	2 (−4; 13)	0.006	−0.486
Interest	−4 (−10; 1)	−3 (−10; 2)	0.812	−0.044
Relaxation	−9 (−23.5; 2.5)	−8 (−25; 1)	0.924	−0.019
Stress	−2 (−23.5; 2)	−2 (−14; 4)	0.538	−0.112

Notes: IR = interquartile range; *p*-value obtained from t-students (parametric) and U de Mann-Whitney (non-parametric); the effect size was calculated using Cohen's *d* for the BES, and Cliff's Delta for the remaining variables comparing 1st VR versus 1st Video.

and focus. Specifically, the group that watched the video first experienced a median two-point increase in excitement and focus, while an eight-point decrease in excitement and a six-point drop in focus was observed in the group that viewed the VR first. No significant changes were observed in the interpersonal index or empathy scores.

Cohen's *d* values below 0.3 suggest minimal differences between groups in the BES. The remaining variables show small to moderate effect sizes, except for the EEG values for interest and stress in VR and for focus in video, which were all above 0.474, suggesting significant differences between the groups.

The data collected on presence reveals no significant differences between participants who viewed the VR format first (1st VR) and those who viewed the video format first (1st Video) for any of the dimensions assessed in the IPQ (Table 4).

Table 5 outlines the main characteristics of the VR experience perceived by participants. In general, it was observed that participants in both groups felt comfortable with the interactive systems offered (interface; 89.5% and 88%). Furthermore, no significant differences were observed in emotional response (either positive or negative) between the two groups, or in the perception of the presence of characters. Although the two groups reported similar levels of connection with the characters, the group that viewed the VR version first identified less with the main character than the group that viewed the video version first. In relation to comfort with the first-person narrative perspective and with sexual and racial diversity, no significant differences were observed between the two groups.

Participants' perceptions of the image quality of the virtual classroom in the VR experience for both groups (Figure 5a) were varied in some respects. For example, while participants who saw the VR version first rated the "artificial" category higher than the 1st Video Group (42.1% vs. 32%), the latter group rated the "surrealistic" category higher (0 vs. 12%). The 1st VR Group also rated the "strange" category higher (10.5% vs. 4%), while there was no significant difference between the two groups in the "impressive" category (21.1% vs. 20%). Finally, the 1st VR Group rated "beautiful" and "cartoonish" higher than the 1st Video Group (5.3% vs. 0% for both categories). Perceptions of the image quality of the children (Figure 5b) also revealed some differences between the two groups. For example, while members of the 1st VR Group were more likely to describe the images as "realistic" (26.3% vs. 16%), the perception that they were "artificial" was more common among members of the 1st Video Group (28% vs. 0%). In addition, perceptions of the images as "surrealistic" and "confusing" were more prevalent in the 1st video group than in the 1st VR group (12% vs. 5.3% and 12% vs. 5.3%, respectively).

Table 4. Results of IPQ for each study group (1st VR and 1st Video).

	1st VR ($n = 19$)	1st Video ($n = 25$)	p-value	Effect sizes
IPQ, median (IR)				
Spatial presence	4 (1; 6)	4 (1; 7)	0.739	−0.061
Involvement	2 (0.5; 5)	1 (−2; 3)	0.278	0.194
Experienced realism	−2 (−2.5; −1)	−2 (−5; −1)	0.290	0.187
General presence	1 (1; 2)	2 (0; 2)	0.626	−0.086

Notes: IR = interquartile range; p-value obtained from U de Mann-Whitney; the effect size was calculated using Cliff's Delta for the remaining variables comparing 1st VR versus 1st Video.

Table 5. Post-viewing description of the characteristics of the VR experience by each study group (1st VR and 1st Video).

	1st VR ($n = 19$)	1st Video ($n = 25$)	p-value
Feel comfortable with the interactive systems offered			0.730
Yes	89.5% (17)	88% (22)	
No	10.5% (2)	12% (3)	
Extent of positive emotional response (e.g., moved, sympathetic, compassionate), median (IR)	7 (4.5; 7)	6 (3; 7)	0.185
Extent of negative emotional response (e.g., uncomfortable, worried, anxious, upset), median (IR)	6 (3.5; 7.5)	6 (3; 7)	0.867
Perceived awareness of presence by character, median (IR)	4 (3; 4)	4 (2; 4)	0.709
Perceived awareness of characters towards participant presence, median (IR)	4 (2; 4)	4 (3; 4)	0.126
Selection of image number (in red) reflecting relationship with narrative characters			0.445
1	15.8% (3)	28% (7)	
2–3	47.9% (9)	40% (10)	
4–5	26.3% (5)	12% (3)	
6–7	10.5% (2)	20% (5)	
Degree of comfort with first-person narrative perspective, median (IR)	3 (2; 3)	4 (2; 4)	0.167
Degree of comfort with diverse sexual orientation kissing, median (IR)	5 (5; 5)	5 (4; 5)	0.443
Degree of comfort in collaborating with team members of different race or sexual orientation, median (IR)	5 (5; 5)	5 (5; 5)	0.168

Notes: IR = interquartile range; p-value obtained from U de Mann-Whitney (continuous variables) and Fisher's exact test or Chi-square test (categorical variables).

Tables 6–10, in the Supplementary File, present results broken down by country, consistent with the findings described above, as no significant deviations were observed in the cross-country comparison.

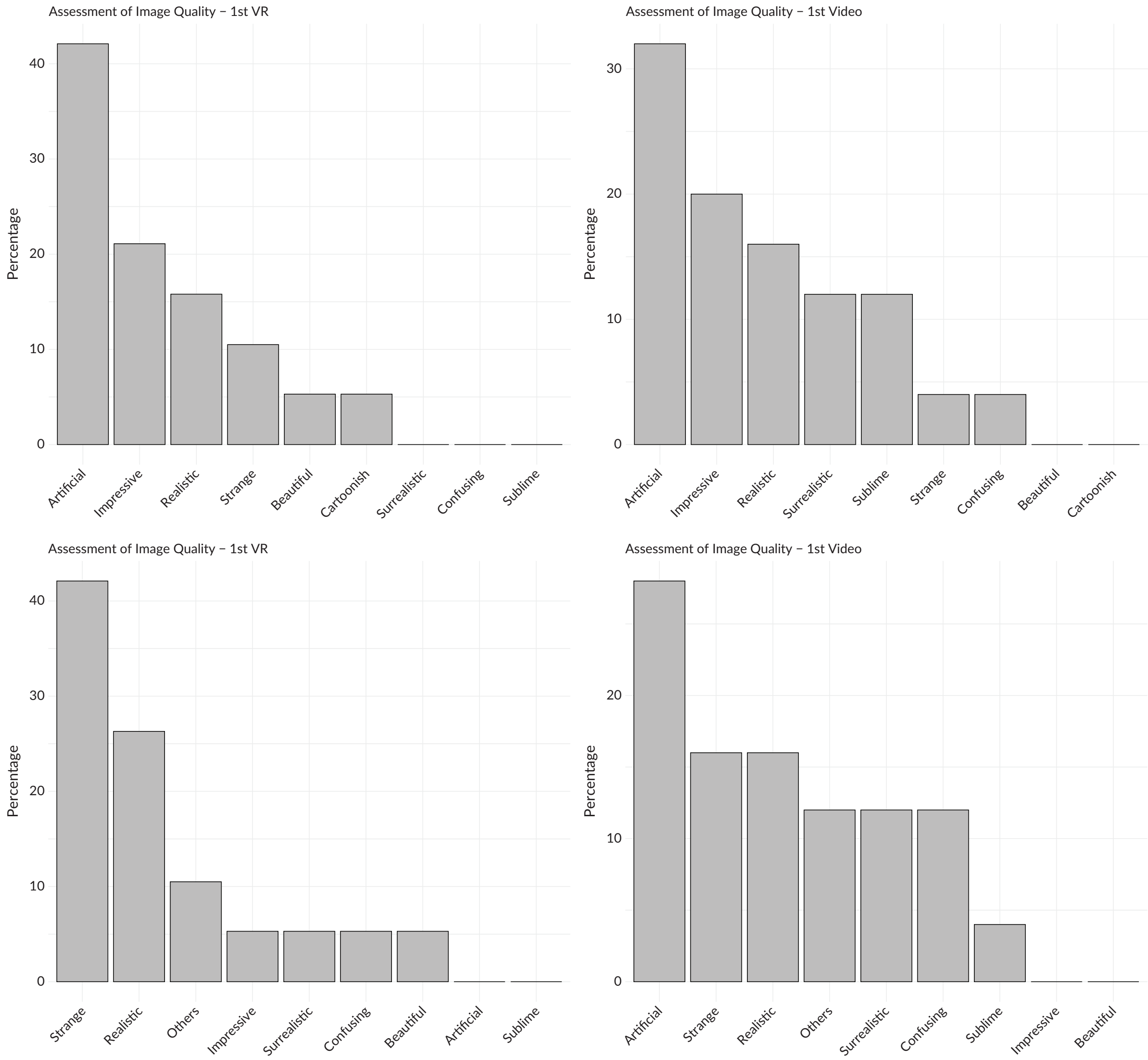

Figure 5. Assessment of image quality of virtual classroom in VR experience (a), and assessment of image quality of children in VR environment (b).

4. Conclusion and Discussion

The results of this study do not establish that the use of a VR narrative is more effective at promoting prosocial behavior than the use of the same narrative in video format, or that the use of VR instead of a traditional screen-based narrative enhances the audience's emotional connection to the narrative content. The drop in the level of engagement between the two key moments of the VR short film was greater in the group that watched the video first, which showed a higher initial level of engagement with the video format, while the group that watched the VR first exhibited no significant change in the level of engagement between the basal and post moments while watching the VR version, and a slightly bigger drop between the two key moments when viewing the video, but the engagement levels in both formats were fairly stable. Although sense of presence has been identified in other studies as one of the key factors behind promoting prosocial behavior using VR experiences, in this study, the VR experience did not show higher levels of presence than the video format, a result that may be associated with the nature of the stimulus itself. Although the immersive stimulus involves 3D recordings of actual actors using volumetric capture, the characteristics of this digital method might induce an uncanny valley effect in participants, thereby impacting the findings related to empathy and engagement. The age disparity between the film's characters and the participants may also have contributed to a sense of detachment, as they no longer relate to the stage of life represented in the film. Sound design, particularly the "boo" subcondition, may have also influenced the level of engagement. This auditory stimulus could have triggered the participants' defensive mechanisms, leading to a subconscious disengagement.

The results also reveal no differences in either positive or negative emotional response between the two groups, suggesting that the prosocial impact of the VR short film was not weaker for the group that viewed the video first, as similar results were obtained for both groups. Thus, in terms of emotional response, the VR narrative had the same impact on both groups. In addition, in the group that watched the video first, the levels of excitement and focus increased by two points between the two key moments of the storyline, while in the group that watched the VR version first, both levels dropped by one point during the VR experience. This finding could be interpreted as indicating that the video format has a greater potential to promote excitement and focus than VR, possibly due to the conditioning of the participants, who have grown up watching audiovisual narratives in 2D formats and are still more accustomed to watching fiction films this way. It is also consistent with the conclusions of Barreda-Ángeles et al. (2020), who contend that immersive media can have the opposite effect of the aim of the narrative due to competitive mediation.

On the question of interpersonal connection and "otherness" in the immersive VR experience, the group that viewed the video format first reported feeling connected to the main character, while the group that viewed the VR version first identified less with that character. This suggests that the order in which formats are viewed may affect audience responses and the impact of narrative content. In this case, viewing the VR version first conditioned the effect of the narrative less than viewing the video format first.

The fact that VR did not have the impact identified in previous studies may also be due to the fact that users are now more familiar with the medium. As Bosworth and Sarah (2018, p. 12) point out, VR has a greater impact on viewers unfamiliar with the technology. In view of these results, it would be advisable to give priority to the narrative over the technological device in order to elicit emotional involvement and prosocial responses from the audience. VR may offer an innovative and more immersive way of storytelling, but it is the story itself that determines the impact on the audience.

Finally, it is important to highlight certain potential limitations of this study. Firstly, although the sample comprises participants from two countries, which may pose an issue in relation to possible cultural differences, the comparative analysis of the data collected by country reveals no significant variations. Secondly, given that participants in both countries might have different linguistic backgrounds, the languages of the stimulus film—shot in Spanish and subtitled in English—could represent a limitation, potentially influencing how participants interpreted the narrative and responded to the stimulus based on their proficiency in Spanish or English. Finally, despite efforts to reduce and shorten the number of survey questions, the extensive use of questionnaires in the study may have induced a fatigue effect in participants, which in turn may have affected the results.

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Conflict of Interests

The author declares no conflict of interests.

Data Availability

The original contributions presented in the study are included in the article/supplementary material; further inquiries can be directed to the corresponding author.

Supplementary Material

Supplementary material for this article is available online in the format provided by the author (unedited).

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ARTICLE

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Informing Immersed Citizens: The Impact of Interactivity on Comprehending News in Immersive Journalism

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Abstract

Immersive journalism has emerged as an innovative journalistic approach promising enhanced attention and understanding through interactive, virtual environments. Previously, this was mostly tested through factual knowledge. However, evaluating immersive audio-visual modalities solely along factual knowledge falls short of considering, firstly, what about and how an immersive experience is remembered and, secondly, the importance of considering the perceptions surrounding information acquisition. Therefore, this study examines how interactivity in immersive journalism affects traditional as well as novel ways of comprehending news, such as episodic memory. In addition, we consider perceptions related to knowledge. We draw on a laboratory experiment (N = 149) testing the effect of three levels of interactivity provided (no interactivity vs. looking around vs. looking around + control over pace and order of storyline). Results indicate that a higher range of interactivity does not influence factual memory, but leads to an increase in perceived knowledge, thus indicating an illusion of knowledge. Moreover, there is a tendency to formulate more subjective takeaways in the high-interactivity condition, while interactivity did not influence the credibility evaluations. This provides partial empirical support for the credibility paradox of immersive journalism.

Keywords

immersive journalism; information retention; interactivity; memory; virtual reality

1. Introduction

Journalism should inform citizens; this normative assumption of journalism vis-à-vis democracy is almost universally acknowledged (Peters & Witschge, 2015; Strömbäck, 2005). Informing citizens typically means that "the news should provide citizens with the basic information necessary to form and update opinions on all of the major issues of the day" (Zaller, 2003, p. 110). Consequently, empirical studies testing the extent to which journalism informs an audience often use factual recall to assess information retention (e.g., Grabe & Myrick, 2016). Immersive journalism (IJ), which was initially thought to improve attention and focus and ultimately inform citizens, was found to instead have a detrimental impact on information retention (e.g., Barreda-Ángeles et al., 2020).

Since 2015, media companies have embraced IJ to emotionally and experientially re-engage and inform audiences (Sánchez Laws, 2019). IJ employs audio-visually immersive technology, such as virtual reality (VR), to let the audience witness a news event or story as if they had been there (de Bruin et al., 2020). This immersion is believed to capture the audience's attention, render split-screening impossible, and invite a deeper and more focused understanding of a subject (Sánchez Laws, 2019, p. 2). Recently, IJ's potential for more extensive interactivity possibilities has received attention due to the assumed engagement potential (Vázquez-Herrero, 2021) and perceived benefit in guiding user attention (H. Wu et al., 2021). Despite the optimism surrounding this potential of interactivity in IJ to help journalism's core function of informing citizens, studies of IJ's effect on information intake surprisingly indicate that IJ has either no (Barnidge et al., 2022; Bujić et al., 2023) or a negative influence (Barreda-Ángeles et al., 2020; Greussing, 2020; Sundar et al., 2017) on factual information intake.

Evaluating immersive audio-visual modalities solely in terms of factual knowledge falls short of considering how an immersive experience is remembered and the perceptions surrounding information acquisition. This line of thinking reflects a trend in visual communication arguing that it is crucial to consider the informational qualities of these visuals (Grabe & Myrick, 2016). Similarly, scholars suggest that IJ is remembered as a prosthetic memory (Dowling, 2022, p. 918). Thus, when evaluating IJ's informational quality, it is crucial to account for its modally rich nature (Dowling, 2022). This becomes even more important when considering that interactivity in IJ seems to be remembered as if it had happened to oneself (Ruddle et al., 2011). In addition, users' perceptions, such as their evaluation of the information's accuracy (e.g., Aitamurto, 2019; Sundar, 2008) and their perception of how much they remember (e.g., Schäfer, 2020), play an important role when assessing whether receiving information prompts individuals to adopt attitudes and behaviors (Grabe & Myrick, 2016; Pilditch et al., 2020; Schäfer, 2020).

This study aims to identify how interactive IJ relates to the democratic function of journalism vis-à-vis its citizens—to inform them (Strömbäck, 2005). We adopt a broader view of how users can be informed through IJ and investigate the impact of interactive IJ on factual recall, episodic and autobiographic memory, and main takeaways. We also explore perceptions such as perceived knowledge gain, credibility, and the completeness of the information received. We test the effect of an IJ experience in which the range of interactivity possibilities is manipulated (no interactivity vs. medium interactivity vs. high interactivity) in a laboratory experiment (N = 149). The data collection was part of a more extensive project and was pre-registered for the larger study.

2. Contextualization of IJ

IJ, positioned at the intersection of the emotional turn (Wahl-Jorgensen, 2020), the audience turn (Costera Meijer, 2020), and narrative visualism (Baía Reis & Coelho, 2018), offers a multi-sensory, user-centric news experience that aims to foster both cognitive and emotional understanding (Bujić & Hamari, 2020; Sánchez Laws, 2019). IJ encompasses three dimensions (de Bruin et al., 2020). First, inclusive technologies refer to the extent to which physical reality is audio-visually shut out or overlaid by VR (de Bruin et al., 2020). Inclusiveness is a core characteristic of immersive technologies (Slater & Wilbur, 1997), and can be placed on a spectrum, from less inclusive technologies, such as augmented reality, to more inclusive technologies, such as VR (Milgram & Kishino, 1994). Second, immersive narratives are narrative structures that provide an active role for the user in the environment (de Bruin et al., 2020). Third, interaction possibilities refer to ways of navigating the inclusive environment. Specifically, interactivity refers to "the extent to which users can participate in modifying the form and content of a mediated environment in real-time" (Steuer, 1992, p. 84; see also de Bruin et al., 2020).

IJ peaked in 2017 when major news agencies such as *The New York Times* and *Euronews* partnered with tech giants like Samsung and Google to fund immersive storytelling (Sirkkunen et al., 2021). Other global news companies followed suit. However, enthusiasm decreased after IJ failed to gain traction on larger platforms like *The New York Times* (Wang et al., 2018). Still, Meta, Apple, and South Korea's investments in VR headsets and the metaverse indicate ongoing hardware and software development (Thompson, 2023). Anticipated improvements in head-mounted display (HMD) quality, affordability, and an expanded media environment through tech giant investment may lead to wider IJ adoption, as an HMD-enabled presence could make IJ more engaging (Greber et al., 2023). In this context, extending interactivity beyond simply looking around is proposed to further increase the impact (Vázquez-Herrero, 2021) and competitiveness of IJ in a highly engaging environment.

3. IJ and Traditional Ways of Informing Citizens

An informed citizenry often lies at the center of normative democratic theories: Citizens should develop an informed opinion, resulting in rational decisions when participating in elections or political discussions (Zaller, 2003). While the extent to which citizens ideally should be informed varies depending on the comprehension of democracy (e.g., thick vs thin), as well as the notion of decision-making processes (e.g., informed decision-making vs. heuristic decision-making), at its core lies the argument that citizens need sufficient information to connect their interests to their political choices (Delli Carpini, 2000). As citizens are primarily informed about politics through the media, this notion has provoked extensive research on how social media platforms influence their users' information acquisition (e.g., Schäfer, 2020). These studies often measure factual recall.

As IJ was initially assumed to inform its users, numerous studies investigated whether this was true. Somewhat surprisingly, studies indicate that IJ either has no effect (Barnidge et al., 2022) or negatively impacts factual recall compared to less immersive formats, particularly when delivered through audio in a 360° video (Barreda-Ángeles et al., 2020; Sundar et al., 2017). Journalists now also highlight the need to reduce the amount of information provided to not overwhelm the audience (Mabrook, 2021).

This negative trend for factual information retention in IJ can be attributed to the cognitive resources required for processing sensory-rich modalities, navigating virtual environments, and experiencing presence (Barreda-Ángeles et al., 2020; Pjesivac et al., 2022). Processing information from a multimodal environment requires more cognitive resources, as each modality adds perceptual information to be processed, limiting the capacity for systematic processing (Fisher et al., 2019). Furthermore, the visual immersion facilitated by one mode, such as a 360° view and interaction possibilities, might impede attention to information conveyed via a different mode, such as audio. However, most factual information in 360° news is presented via audio rather than visuals (Barreda-Ángeles et al., 2020). Incorporating interactivity in IJ likely increases the cognitive demand on users (Bowman, 2021), adding to the challenge of remembering factual information provided in a voiceover. Studies suggest that VR interactivity indeed negatively influences factual knowledge gain via embodied learning (Petersen et al., 2022). Thus, highly interactive IJ is likely not beneficial for learning facts:

H1: Interactivity in IJ decreases factual recall.

Interaction possibilities in journalistic storytelling reflect a power struggle for narrative control; journalists are wary of losing their role in contextualizing events (Peters & Witschge, 2015). Journalists report concerns related to interactivity in IJ, as it increases users' control over their information intake, which may lead users to focus on a story's specific viewpoints while disregarding others (Mabrook, 2021). The fear is that interactivity in IJ could result in a subjective understanding and takeaway from a news story, thus enhancing "user-induced subjectivity" (Aitamurto, 2019; Mabrook, 2021, p. 209). However, whether this tendency exists when consuming interactive IJ has, to the authors' knowledge, not yet been investigated empirically:

RQ1: How does more interactivity in IJ influence the main takeaways of the audience?

4. IJ and Its Novel Way of Informing Citizens

Arguably, evaluating whether citizens are better informed after experiencing IJ mainly based on understanding facts and their main takeaways falls short of considering that audio-visual immersive media are experienced and, consequently, remembered differently than, for instance, text (e.g., Sundar et al., 2017). The tendency to evaluate information intake based on facts relates to traditional ways of informing citizens, such as high-quality, text-based newspapers, as bringing about informed citizenship (Grabe & Myrick, 2016) as well as the aforementioned concept of the informed citizenry (Delli Carpini, 2000). However, as Grabe and Myrick (2016) argue, in a high-choice media environment where people increasingly consume often emotional (audio-)visual information (Newman et al., 2023), we should conduct research on the informational value of visuals. A similar debate evolves from the emotional turn within which IJ is set, where the informational value of emotions is highlighted (Bas & Grabe, 2015; Wahl-Jorgensen, 2020). In IJ, investigating how visuals are remembered is even more important when considering that factual information in IJ is often transmitted via audio, while users are visually and bodily immersed in the news experience (Barreda-Ángeles et al., 2020). However, previous research indicates that visuals are more likely to be remembered when visual and audio stimuli are presented simultaneously (Lang et al., 1999). Arguably, as IJ exemplifies an experiential, modal-rich account of the news that users experience much closer to how they perceive reality than a traditional news format (Sundar, 2008), it has *novel ways of informing citizens*. We need different measures and perspectives evaluating IJ's potential to be remembered.

This notion is also reflected in discussions surrounding IJ's additional information layer. For instance, remembering IJ can be understood as a form of prosthetic memory: Media "functions as a kind of stand-in for real experiences that nonetheless bears a lasting impact recalled as if the individual were physically present" (Dowling, 2022, p. 918). Schlembach and Clewer (2021) suggest that eliciting prosthetic memory is central to assumptions about VR's potential power: Factual knowledge seems insufficient as the aim for serious VR experiences, and individuals instead need to be "made to feel" potentially terrifying experiences to elicit societally beneficial outcomes. Kool (2016) broadly agrees with this in their analysis of the 360°, documentary-style production *Clouds Over Sidra*, highlighting that by remembering a VR experience as if it happened to oneself, the experience "becomes a personally relevant lived experience" (p. 6). Importantly, not all IJ experiences are produced with the aim of eliciting such a personally relevant experience. While some, such as character-led first-person experiences, are produced with the intention to let the audience witness a news event as if they were there, others are produced with the intention to lead a passive audience through a news story, such as reporter-led narratives (Jones, 2017; Nyre & Vindenes, 2021). Regardless of these differences in production, the inclusive and interactive nature of IJ might still be remembered by the audience as a form of prosthetic memory.

Relatedly, psychologists are interested in examining to which extent memory can be experimentally investigated in VR. These studies indicate that VR experiences can indeed be remembered in the form of episodic and autobiographic memory (Smith, 2019). Episodic memory was originally defined as remembering "information about temporally dated episodes or events, and temporal–spatial relations among these events" (Tulving, 1972, p. 385). More recently, episodic memory has also been found to encompass a "sense of self-awareness and a subjective conscious experience" (American Psychological Association, 2023b). Studies evaluating VR environments find visual fidelity (Wallet et al., 2011) and active navigation (Ruddle et al., 2011; Sauzéon et al., 2012) to be positively related to episodic memory. However, while certain forms of interactivity, such as active choice in navigation, might improve episodic memory, other forms, such as including highly complex motor control, might lead to worse episodic memory, likely due to the high cognitive burden placed on individuals in those conditions (Plancher et al., 2013). Moreover, much literature focusing on the impact of interactivity on episodic memory lacks the inclusion of a passive experimental condition, resulting in calls for studying this phenomenon with a non-interactive condition (Smith, 2019). Autobiographic memory is "a memory of a personally experienced event that comes with a sense of recollection or reliving" (Greenberg & Rubin, 2003, p. 688). It includes self-referential processing in remembering events (Cabeza et al., 2004), which often encompasses a reliving of emotions and recalling spatiotemporal contexts in contrast to episodically recalling laboratory contexts (Svoboda et al., 2006). Autobiographic memory can encompass information that is stored as both episodic and semantic memory (American Psychological Association, 2023a). While videos shown in laboratory settings are remembered as isolated episodic events, VR experiences tend to be recollected in an autobiographic manner (Kisker et al., 2021b; Schöne et al., 2019). As a consequence, such VR experiences seem to elicit real-life behavior, such as anxiety and physiobiological responses in a height exposure experiment (Kisker et al., 2021a).

Thus, while it seems likely that VR experiences aiming to recreate a realistic environment result in a form of visual episodic or autobiographic memory encoding, IJ may be different. IJ differs from psychological stimuli in that it typically entails clear signs of journalistic mediation, such as narrators and sources, and their interaction possibilities rarely change the outcome of an IJ story (S. Wu, 2023). In addition, the most common form of IJ encompasses 360° videos with high journalistic narrative control, therefore focusing on storytelling and limiting realistic exploration (Rodríguez-Fidalgo & Paíno-Ambrosio, 2022). Therefore, this assumption has yet to be tested for journalism:

H2: Interactivity in IJ results in more episodic and autobiographic memory encoding.

5. IJ and Evaluation of Information

It is also crucial to assess users' perceptions of the information and their information intake in IJ to enhance the evaluation of IJ's potential impact and effectiveness in informing citizens, as they can substantially impact the formation of attitudes and behaviors (e.g., Grabe & Myrick, 2016; Pilditch et al., 2020; Schäfer, 2020). One crucial perception relates to credibility evaluation—that is, is the information presented perceived as accurate, plausible, and authentic? Following the MAIN theory (Sundar, 2008), the "realism heuristic" suggests that the more realistic and close-to-life a message is conveyed, the more users evaluate it as credible. Indeed, 360° videos are evaluated as more credible (Kang et al., 2019) and trustworthy (Sundar et al., 2017) than normal videos. Additionally, more interactive IJ is evaluated as more accurate than its non-interactive counterparts (H. Wu et al., 2021). Credibility evaluations are related to belief uptake, regardless of whether the information presented is factually correct or not (Pilditch et al., 2020). Paradoxically, interactivity might simultaneously create a perception of accuracy while potentially resulting in a more fragmented understanding, rendering interactive IJ de facto less accurate (Aitamurto, 2019).

Another approach to evaluating whether participants feel their experience was comprehensive—specifically relevant for IJ—is the fear of missing out (FOMO). For VR, FOMO refers to individuals feeling that they are missing important information at their virtual backside due to the omnidirectional view (Aitamurto et al., 2018). Indeed, participants seem to experience more FOMO after experiencing 360° videos than normal videos (Aitamurto et al., 2018), which could mean that the experience is perceived to be less comprehensive. Adding more interactivity could thus facilitate the FOMO experience.

Furthermore, IJ's immersive audio-visual nature might result in an increased perceived knowledge gain, which could indicate an illusion of knowledge (Schäfer, 2020). Brucks (1985) differentiates between objective and subjective knowledge, where objective knowledge refers to the extent to which individuals identify factually correct information, while subjective knowledge refers to the extent to which individuals assess how much they know about a given topic. As such, an illusion of knowledge can be defined as the difference between low factually correct knowledge about a topic and high perceived knowledge about a topic (Kim, 2019). The reason why a higher range of interactivity in IJ might elicit an illusion of knowledge is linked to the processing fluency theory, which shows that the more fluently information is processed, the more it tends to increase perceived knowledge but not actual knowledge (Frauhammer & Neubaum, 2023). The cognitive load of simultaneously encoding perceptual information from different modalities means that modal-rich formats might not undergo thorough processing (Fisher et al., 2019), which might be responsible for lower factual information retention. Rather, they tend to be processed automatically and more fluently, thereby facilitating perceived knowledge (Sundar et al., 2021). Processing fluency is increased when audio-visual modalities are used (Ryffel & Wirth, 2020). Indeed, interactivity in immersive environments has previously been found to increase perceived but not actual knowledge gain (Aitamurto et al., 2020). A higher range of interactivity might increase cognitive load and, thus, be processed more fluently, leading to perceived knowledge gain:

H3: Interactivity in IJ increases perceived credibility;

H4: Interactivity in IJ increases FOMO;

H5: Interactivity in IJ increases perceived knowledge gain.

6. Method

A laboratory experiment ($N = 149$) was conducted with one IJ experience varying along a range of interactivity (Steuer, 1992, p. 104). Interactivity can be differentiated along its range, which means that "the greater the number of parameters that can be modified, the greater the range of interactivity" (p. 104). The IJ experience (Figure 1) *Hanen's Story* about a Syrian family in a Greek refugee camp, produced by Wiener Zeitung and Junge Römer, was used as a stimulus. In the no-interactivity group ($n = 52$), participants viewed a video. In the medium-interactivity group ($n = 45$), participants experienced a 360° video, enabling omnidirectional view exploration. The high-interactivity group ($n = 52$) viewed the same 360° video but with a map of the refugee camp, which participants could use to navigate through the scenes. As such, each manipulation of interactivity adds new parameters that can be influenced by the users, thus corresponding to the range of interactivity as defined by Steuer (1992). The duration of the experience in the no- and medium-interactivity conditions was 5 minutes and 25 seconds; the high-interactivity experience took $M = 7$ minutes ($SD = 1.7$ minutes). All conditions were shown through a Meta Oculus Quest 2.

Participants completed a comprehensive health screening, provided informed consent, and were familiarized with the equipment. Then, they completed a questionnaire covering control variables and were randomly assigned to one of the three treatment conditions. After the IJ experience, participants answered an extensive questionnaire. At the end, participants received a reward of 15 EUR. Data were collected from 06.06.2022 to 30.09.2022 as part of an extensive data collection project on IJ, which was approved by the institutional review board of the University of Vienna (IRB 20220427_016). The power analysis, data analysis plan, survey questionnaire, hypothesis, and stimulus were pre-registered for the full project; the dataset, R-scripts, and Appendix are also made available on OSF (https://osf.io/x2wbz/?view_only=14daacf13d104f02abf010951913f23b); alterations from pre-registration are listed in Appendix E.

Figure 1. Screenshots of stimulus material: (a) no interactivity; (b) high interactivity; (c) beginning scene of the experience.

6.1. Measures

Cued recall was tested with seven multiple-choice questions, each presenting three incorrect and one correct choice (Bujić et al., 2023; Sundar et al., 2017). This is a common approach used within the LC4MP literature to test information storage (Fisher & Weber, 2020). All questions referred to information provided in a voiceover. The final measure is the overall correct score of the answers, ranging from 0 (*no answer correct*) to 7 (*all answers correct*; *M* = 5.27, *SD* = 1.06).

To assess the participants' main takeaways, open responses to the following question were collected: "What was the main takeaway from the production you just saw?" The lead author conducted inductive thematic analysis (Clarke & Braun, 2014) on the answers. Inductive coding was conducted until theoretical saturation was reached—i.e., when 10% (*n* = 15) of cases failed to generate a new code—at *n* = 71. Seven themes were identified. Appendix B (Table 14) presents a detailed description of each theme, including references to the stimulus text.

To test autobiographical memory, following Kisker et al. (2021a, 2021b), participants sorted 12 pictures—six correct and six incorrect (see Appendix C)—along the remember/know paradigm (Kisker et al., 2021c; Tulving, 1993), where remembering refers to a conscious recollection of knowledge, indicating autobiographic memory, and knowing refers to knowledge that is familiar, but not consciously retrieved (Tulving, 1993). Participants sorted visuals as being "definitely unknown," "rather unknown," "familiar," or "vividly remembered" (Kisker et al., 2021c). The six correct pictures were screenshots of the stimulus, while the six incorrect pictures were screenshots of another video shot on the same day in the same refugee camp, depicting similar scenes. The performance measures are calculated as a d' (prime) score (Haatveit et al., 2010). A participant's performance in a task improves when they maximize hits and minimize false alarms. A positive d′ suggests that performance is better than chance (Haatveit et al., 2010). A general retrieval score is calculated as d'-general retrieval score = z(vividly remember hits + familiar hits) − z(vividly remember false positives + familiar false positives). The recollection score indicates "recollection-based judgments," typically related to autobiographic memory retrieval (Kisker et al., 2021b), calculated as d'-recollection score = z(vividly remember hits) − z(vividly remember false positives). The familiarity score indicates judgments related to the know part of the remember/know paradigm (Tulving, 1993), calculated as d'-familiarity score = z(familiarity hits) − z(familiarity false positives).

As episodic memory includes the temporal encoding of information (Tulving, 1993), participants were asked to sort the six correct visuals from the previous task in the order they encountered them during the experience (Wallet et al., 2011). Following previous literature (e.g., Ruddle et al., 2011), the Levenshtein distance algorithm was calculated to indicate the minimum number of edits required to correct the sequence (Levenshtein, 1966). The score ranged from 0 (*no alignment with correct order*) to 6 (*perfect alignment with correct order*; *M* = 2.36, *SD* = 1.50).

Credibility was measured using six items based on Kang et al. (2019), measured on a scale from 1 (*do not agree*) to 7 (*strongly agree*; *CA* = .745; *M* = 5.00, *SD* = 1.02; Mcgrath & Gaziano, 1986). FOMO was tested with a three-item scale based on Aitamurto et al. (2018), from 1 (*do not agree*) to 7 (*strongly agree*; *CA* = .694; *M* = 2.85, *SD* = 1.43). Three items testing perceived knowledge gain were included (Aitamurto et al., 2020; Kim, 2019), measured on a scale from 1 (*do not agree*) to 7 (*strongly agree*; *CA* = .795; *M* = 4.62, *SD* = 1.40).

Extensive quality checks (a-priori pre-registered power analysis, attention checks, randomization checks) were conducted and are reported in detail in Appendix F. In line with Steuer (1992), who argues that "interactivity is a stimulus-driven variable, and is determined by the technological structure of the medium" (p. 104), the differentiation between the experimental groups is based on concrete technological functionalities, not on the subjective evaluation of interactivity by participants; thus, no manipulation check is conducted (also see O'Keefe, 2003). Nonetheless, see Appendix F for an analysis of the impact of interactivity in IJ on the sense of agency and sense of presence. The analysis included 149 participants; the average age was 26.76 (*SD* = 10.12), and 54.4% were female. The majority had completed their Matura (Austrian equivalent of A-Levels, 39.6%), followed by bachelor's (23.5%), master's (16.1%), practitioners' Matura (10.1%), other education (3.4%), and PhD (2.7%). Randomization checks were successful for all variables aside from familiarity with VR; thus, familiarity is added to all analyses as a control variable. Appendix D reports analyses without familiarity as a control; the results remain largely the same.

7. Results

Ordinary-Least-Squares regressions were conducted to test the pre-registered hypotheses. Groups were dummy-coded (0 = *less interactive*, 1 = *more interactive version*).

7.1. H1 and RQ1: Factual Information Retention and Main Theme

H1 assumes that the higher the interactivity range, the less factual information participants remember. The results show no significant effect of the three experimental conditions on recalling facts (Appendix A, Table 6). Thus, IJ interactivity does not negatively influence cued recall. H1 is rejected.

RQ1 examines the influence of interactivity in IJ on the main theme perceived by the audience. Overall, the order in which participants encountered information seems to influence what they assessed as the story's main theme. In the no-interactivity condition, individuals tended to derive their theme from the last third of the story. In the medium-interactivity condition, participants tended to show a less rigid connection to the narrative's chronological sequence, focusing on the story's early and late segments. Meanwhile, in the high-interactivity condition, main themes tended to be phrased generally, instead of reiterating specific story segments. Emerging themes in the high-interactivity condition tended to relate to refugee camp life and a sense of instability. Notably, participants in the high-interactivity condition seemed more inclined to include their own interpretation in defining the main theme, rather than reiterating or summarizing what the story directly addressed. This might suggest that the impressions individuals derive from highly interactive experiences are less organized, more abstract, and more influenced by their existing predisposed viewpoints.

7.2. H2: Episodic and Autobiographical Memory

H2 assumes that more interactivity in IJ means that participants are more likely to remember IJ as part of their episodic memory, as well as autobiographical memory. Recalling the experience in temporal order was measured as an indicator of episodic memory. Data analysis indicates no significant difference between the high-, medium-, and low-interactivity conditions (Table 1), suggesting no episodic memory retrieval when considering episodic memory's temporal aspect.

Table 1. Influence of IJ interactivity on episodic memory (sorting task), general visual retrieval, recollection score, and familiarity score.

	Episodic memory	General visual retrieval	Recollection score	Familiarity score
	B (*SE*)	B (*SE*)	B (*SE*)	B (*SE*)
High-interactivity (no-interactivity)	.341(.296)	.546^{+}(.314)	–.046(.252)	.592^{+}(.304)
High-interactivity (medium-interactivity)	.059(.339)	–.010(.318)	.057(.293)	–.066(.295)
Medium-interactivity (no-interactivity)	.263(.287)	.548^{+}(.289)	–.084(.281)	.632(.285)*
Num.Obs.	104/97/97	104/97/97	104/97/97	104/97/97
R2	.014/.001/.014	.056/.052/.066	.003/.003/.009	.052/.041/.057
R2 Adj.	–.005/–.020/–.007	.038/.032/.046	-.016/-.018/-.012	.034/.020/.037

Notes: $^{+}$ $p < .1$; * $p < .05$; ** $p < .01$; *** $p < .001$; control on familiarity with VR.

Moreover, there is no difference between the high-, medium-, and low-interactivity conditions in the general visual recognition performance task (Table 1). However, the marginally significant results suggest that the medium- and high-interactivity conditions might result in better overall visual retrieval than the no-interactivity condition. The Mahalanobis distance indicates two strong outliers (*M-distance* = 14.267, 11.128). When excluding these, the difference between medium- and no-interactivity approaches marginal significance ($b = .569$, $p = .053$), and the difference between high- and no-interactivity becomes significant ($b = .664$, $p = .031$).

Furthermore, when breaking down the visual recognition score into recollection (i.e., autobiographic) and familiarity components, the data indicate that the visuals in medium-interactivity ($b = .632$, $p = .029$) and, marginally, the high-interactivity ($b = .592$, $p = .054$) condition tend to more likely trigger familiarity responses than in no-interactivity. However, there is no difference between high-interactivity and medium-interactivity conditions. The conditions also do not significantly affect recollection-related retrieval (i.e., autobiographic memory). Overall, these findings suggest a tendency of visuals to be better recognized in the medium- and high-interactivity conditions, indicating a form of personal involvement (Schöne et al., 2019). However, the increased performance does not seem to rely on autobiographical memory encoding, as indicated by the non-significant recollection score, but rather on familiarity-based knowing. A similar pattern for the familiarity score can be found in Kisker et al. (2021b), even though in that study the pattern appears for the computer-condition in contrast to the VR-condition. Consequently, our results could indicate that more interactivity in IJ might be remembered in a superficial episodic manner similar to computer-based psychological treatments rather than VR-based psychological treatments. H2 is partially accepted.

7.3. H3, H4, H5: Credibility, FOMO, Perceived Knowledge Gain

Against theoretical expectations (Sundar, 2008), increased interactivity does not result in more credibility (Table 2). H3 is rejected.

H4 assumes that more interactivity increases FOMO. In the medium-interactivity condition (M = 3.26, SD = 1.44), participants experienced significantly more FOMO than for both no-interactivity (M = 2.51, SD = 1.39; b = .756, p = .012) and high-interactivity (M = 2.78, SD = 1.36; b = –.567, p = .048). There is no difference between the high- and no-interactivity conditions. In the 360° experience, participants might be more aware of options they cannot access compared to the no- and high-interactivity conditions, increasing their perception of not getting a comprehensive view. H4 is partially accepted.

H5 hypothesizes that participants with more interaction possibilities have higher perceived knowledge gain. Indeed, both high-interactivity (M = 4.94, SD = 1.42; b = .723, p = .016) and medium-interactivity (M = 4.74, SD = 1.13; b = .590, p = .037) result in more increased knowledge perception than no-interactivity (M = 4.18, SD = 1.50). There is no significant difference between the high- and medium-interactivity conditions. H5 is partially accepted.

Table 2. Influence of IJ interactivity on credibility, FOMO, and perceived knowledge.

	Credibility	FOMO	Perceived knowledge
	B (*SE*)	B (*SE*)	B (*SE*)
High-interactivity (no-interactivity)	.105(.205)	.191(.277)	.723(.295)*
High-interactivity (medium-interactivity)	.052(.215)	–.567(.284)*	.204(.265)
Medium-interactivity (no-interactivity)	.114(.207)	.756(.293)*	.590(.280)*
Num.Obs.	104/97/97	104/97/97	104/97/97
R2	.019/.007/.004	.023/.059/.89	.068/.008/.046
R2 Adj.	.000/–.014/–.017	.004/.039/.069	.050/–.013/.026

Notes: * $p < .05$; ** $p < .01$; *** $p < .001$; control on familiarity with VR.

8. Conclusion

This study investigated how IJ might contribute to journalism's aim of informing citizens. Results indicate that, concerning traditional approaches, interactivity in IJ does not affect factual recall; however, qualitative data analysis suggests it is related to higher subjectivity in the main takeaways. Regarding novel ways of informing citizens, high interactivity in IJ tends to enhance performance in a visual recognition task and result in familiarity-based remembering, indicators for shallow episodic memory retrieval (Kisker et al., 2021b). The findings further suggest interactivity in IJ might result in an increased illusion of knowledge, i.e., a gap between factual and perceived knowledge gain (Kim, 2019). Together, this suggests that IJ might not be suited to informing citizens about facts but is suited for communicating experiences to individuals with the aim of being remembered as if one were there.

While participants in the medium- and high-interactivity conditions did not recall more information (see Barreda-Ángeles et al., 2020; Bujić et al., 2023), they thought they knew more than those who only saw a video (see Aitamurto et al., 2020), resulting in a gap between factual and perceived knowledge gain, which can be interpreted as indicating an illusion of knowledge (Brucks, 1985; Schäfer, 2020). An illusion of knowledge is often related to democracy-related negative consequences, such as not being better informed about a topic but showing an increased willingness to discuss an issue and taking on more extreme viewpoints (Schäfer, 2020). Rather than addressing superficial knowledge intake, IJ could exacerbate the illusion of knowledge trend also seen in other media environments (Schäfer, 2020). However, the perceived knowledge in IJ might relate to knowledge aspects that are not factual. For instance, the findings suggest that participants in the medium- and high-interactivity conditions tend to perform better on a visual recognition task. Consequently, future studies should aim to identify whether a perceived knowledge gain in this context indicates an illusion of knowledge or whether it could relate to other forms of understanding, such as visual comprehension or process-related knowledge.

Second, this study partially confirms the credibility paradox presented by Aitamurto (2019) from an effects perspective. The paradox outlines that while the audience might perceive them as more accurate (see Kang et al., 2019), interactive possibilities might result in more subjective takeaways, thereby making the experience de facto less accurate. Concerning its first premise, our results, in line with more recent findings (Greussing, 2020; Weikmann et al., 2024), indicate that medium- and high-interactivity IJ videos are not perceived as more credible than normal videos. These results question the assumption that more modally rich media are more credible (e.g., Sundar, 2008). Concerning the paradox's second premise (Aitamurto, 2019), the results indicate that individuals might have a more subjective takeaway when controlling their experience's linearity. Thus, journalists' concerns about providing the audience with too much narrative control (Mabrook, 2021) might be justified.

Third, the visual performance tasks indicate that participants, in contrast to psychology findings (Kisker et al., 2021c; Schöne et al., 2019), might not have encoded the IJ experience as autobiographical memory but more likely tended to encode it as a shallow form of episodic memory that is typically associated with computer-based laboratory experiences (Kisker et al., 2021b). IJ is different from psychological stimuli in that the most common formats of IJ typically carry markers of its journalistic mediation (e.g., S. Wu, 2023), thus differentiating it from psychological VR experiences, or IJ experiences with the aim of creating a witnessing experience (Nyre & Vindenes, 2021). However, a different immersive journalistic stimulus than used in the conducted experiment, which is aimed at re-creating an event as it happened, without strong journalistic mediation, and including high-fidelity audio, might be remembered as a form of autobiographic memory (Davis et al., 1999). Therefore, this finding requires future, iterative research focused on diverse formats of IJ, as the question of how IJ is remembered might be important to inform ethical debates (Schlembach & Clewer, 2021). Beyond ethical considerations, in the current foreshadowing of a potential metaverse, it is crucial to investigate further what consequences such an episodic form of memory encoding might have for democratic processes. For instance, episodic memory induction can facilitate risk-taking when making decisions (St-Amand et al., 2018). How might this be related to political decision-making?

This study comes with limitations. First, it is difficult to disentangle the effect of interactivity vs. inclusive technology between the no- and medium-interactivity experimental conditions, as an increase in navigational interactivity also requires an increase in inclusive technology. Second, the findings concerning autobiographical and episodic tendencies to remember an IJ story should be tested with different stimuli and larger sets of visual sorting to ensure their robustness. Moreover, psychological studies often assess autobiographical recollection 24 to 48 hours post-experience (Kisker et al., 2021b), which was not feasible for this study. Third, the study represents a single-message design; thus, it cannot assess whether the effects remain robust beyond the particular topic (Thorson et al., 2012). Therefore, this study should be replicated with several topically diverse stimuli, and a more diverse sample concerning age and educational backgrounds. Future studies should also include a broader objective knowledge quiz that goes beyond measuring factual recall to assess an illusion of knowledge. In addition, a follow-up on this study could test whether the results on the illusion of knowledge are indeed related to cognitive demands, as suggested in prior literature (Barreda-Ángeles et al., 2020; Pjesivac et al., 2022).

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Conflict of Interests

The authors declare no conflict of interests.

Data Availability

The pre-registration, as well as the Appendix, questionnaire, datasets, and R-scripts can be found on OSF as part of the larger project on immersive journalism here: https://osf.io/x2wbz/?view_only=14daacf13d104f02abf010951913f23b

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Augmented Landscapes of Empathy: Community Voices in Augmented Reality Campaigns

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Abstract
In contrast with virtual reality which often aims to isolate a user from their surroundings in order to transport them to a distant place, augmented reality (AR) was uniquely designed to (re)contextualize local landscapes and to provide expanded human experiences in situ. This critical reflection adopts a “research through design” process to examine AR's technological and affective capabilities in the context of three community co-created AR campaigns. We discuss how AR can become both a conceptual and practical tool for creating conditions of self-identification and, potentially, empathy between audience and content. Further, we explore how people and place become a critical part of AR's infrastructure through the practice of empathic feedback loops.

Keywords
augmented reality; community research; empathy; research through design

1. Introduction

Extended reality (XR) technologies comprising virtual, augmented, and mixed reality tools, have become colloquial terms and a habitual media practice for many people. Yet, while these technologies have recently catapulted into the spotlight following the Covid-19 pandemic and a string of highly publicized industry developments, critical academic research has moved at a more tempered pace. In addition, while XR is useful as an umbrella term to refer to a relatively new category of embodied and interactive spatial media experiences, its three key components have significantly different affordances and require individual attention. Subsequently, this article tackles one of these components, augmented reality (AR), and its relationship to one of the most popular and problematic keywords attached to XR media use: the ability to evoke "empathy."

We argue that in contrast to virtual reality (VR) which often aims to isolate a user from their surroundings in order to transport them to a distant place, AR was uniquely designed to (re)contextualize local landscapes and to provide expanded human experiences in situ. Thus, taking this central function of AR as our departure point, we ask: How can we rethink the mediation of affect and empathy in more productive and ethical ways? Furthermore, what can this process teach us about the medium of AR? To explore these questions, we engage with critique about the framing of empathy in XR media experiences and examine how AR can become both a conceptual and practical tool for creating more just conditions for self-identification and, potentially, empathy between audience and content.

Our critical reflection is grounded in the lived experiences of three innovative pilot campaigns that use AR to promote pediatric vaccinations within the Black community of a major US city. Specific attention is paid to the experiences of Black mothers and caregivers, a population often marginalized in discussions about XR and technology more broadly (Nakamura, 2013). Using a "research through design" process (B. Gaver & Bowers, 2012) we map out key junctures throughout our community co-created campaigns to illustrate the potential for empathetic connections across digital and physical sites. Thus, we interrogate the practice of empathy in the specific context of AR and glean insights about the means through which AR media, as a unique visibility management device, shapes the creation of meaning. We propose that when strategically placed and critically approached within community landscapes, AR can create empathic feedback loops. This is in sharp contrast to many digital applications that overlook community contexts and provide decontextualized, vague user feedback. Our research contributes to ongoing debates about how XR and specifically AR media can ethically evoke empathy (Davis, 2023; Nakamura, 2020) and to a more thorough understanding of AR as a medium.

1.1. AR and Its Contents

Most people access AR media, like games or various filters and apps to enhance one's physical context, directly from their smartphone. As such, AR is by far the more widespread set of technologies from the XR spectrum, with some reports estimating that in 2024 there are close to 2 billion active user devices (Alsop, 2024a) in contrast with 24 million VR headsets worldwide (Alsop, 2024b). The modern history of AR is often traced back to the early 1960s, when computer scientist Ivan Sutherland developed the "Sword of Damocles," a head-mounted display that would allow a person to see computer-generated graphics overlaid on top of their physical surroundings. However, while the technological experience behind AR has significantly evolved today—it is no longer necessary to wear a head-mounted display that is so heavy it needs to be suspended from the ceiling—the concept of AR largely remains tethered to the "overlay" of the virtual on top of the real (Bower et al., 2014).

As several scholars have pointed out, this description misses much of the socio-technical nuance inherent to how AR functions (Healey, 2021; Heemsbergen, 2023), and it forecloses possibilities for understanding active users' reception practices (Livingstone & Das, 2013). This description also obscures the analytical opportunity to fruitfully connect AR media experiences to the broader "spatial turn" happening across the social sciences (Warf & Arias, 2009). In turn, there have been some efforts to advance our understanding of AR by shifting the focus toward its socio-technical functions and exploring its relationships with the environment. For instance, Alha et al. (2023) advocate for the re-framing of AR not as a single technology, but as a cultural practice that augments our space via a plurality of technologies. Heemsbergen (2023) focuses on AR's interactions with the local context and argues that AR media could be "described as relations between computing-data and environment made perceptibly real." Through this shift, Heemsbergen critiques the now standard description of AR as the layering of virtual content on top of a real, physical setting, and instead asks us to move beyond thinking in layers and toward mediations between those layers. In fact, Heemsbergen provocatively problematizes the hierarchical atomic–electronic divide:

> The physical world and reality are not interchangeable concepts; differences between reality and our perception of it range from biological to sociological mediations. Are glyphs virtuality or reality when carved into rock? Layered on paper with graphite? Shone through liquid crystal? How do any of these media make reality? (Heemsbergen, 2023)

In other words, Heemsbergen urges us to consider how meaning is created via the mediation of the environment and the subsequent interaction between the content and the user.

There have been efforts to advance our understanding of AR by critically examining its ideological work, too. For example, Healey (2021) emphasizes the need to prioritize social and ethical definitions of augmentation over technical ones and encourages us to think about what is being mediated and amplified socially, politically, and ideologically through AR. This is particularly important when we consider augmentation as a practice that is not simply "additive but transformative" (Healey, 2021, p. 104). Subsequently, scholars have argued that AR is better aligned with civic-style media than VR due to the possibility for "a more complex and genuine experience between location and media content" (Friesem, 2021, p. 39). In short, AR dynamically channels and expands rather than substitutes our visually perceived contexts and creates opportunities for localized experiences. Through our work, we offer some critical reflections that further extend the notion of AR as a cultural practice, embedded and enacted within local spaces, by specifically focusing on community as a collective actor in the sense-making process. We also interrogate how the community co-creation and use of AR may lead to conditions of self-identification and empathy.

1.2. Locating Empathy in XR Media

Empathy has emerged as a key term in the vocabulary of XR technologies. It has raised much hope for the pro-social uses of XR amongst some communities and, simultaneously, garnered much criticism amongst others for the ways it has been instrumentalized to further entrench social inequalities. For a history of the modern attachment and subsequent detachment of empathy to XR media in the US, including the marginalized roles and imaginaries emanating from female creators, see Messeri (2024). For the purposes of this article, we will highlight the fundamental quality of embodiment, which is present across the XR spectrum (meaning it is exhibited, albeit in different ways, across augmented, mixed, and virtual reality media), as a precursor to creating a sense of empathy. In the context of XR, we understand embodiment as the mutually constitutive relationship between one's physical environment, body, motion, and virtual media components. Indeed, the synergy between these elements is necessary for the very consumption of XR media content and for meaning-making processes to occur. However, we argue that embodiment is experienced differently, and, furthermore, that there are productive differences in its operationalization between VR and AR media.

It is also worth noting a series of highly publicized XR products as another reason why empathy has emerged as an XR keyword. These include Milk's (2015) TED talk, where he described VR as the ultimate "empathy machine"—a soundbite that itself has generated significant reaction amongst academia and industry—and a strong corporate push to market "good" uses of XR. In a capitalist society underpinned by various strands of techno-solutionism, it seems like a natural extension that more advanced technologies solve our more advanced problems. It is here that we contend AR media could, through careful design, invert some of this problematic logic. Before we delve into how, it is worth also examining what we mean by empathy and disentangling the problematics of current XR-empathy operationalizations.

In this article, we understand empathy as the ability to connect, logically and emotionally, to the perspective of another (Cuff et al., 2016). This is different from sympathy, which can exacerbate distance between self and Other by creating a remote awareness of another's plight (Wispé, 1986). Empathy is often separated into various dimensions (Batson, 2009) including cognitive (knowing another's internal state), aesthetic (projecting what another is feeling), and affective or empathic distress (physiologically feeling what another is feeling). It has been described as an evolutionary response to babies and children (de Waal, 2005), which is noteworthy given our context of pediatric health messaging. Empathy has also been separated into "types" (Batson, 2009): reactions that aim to perceive the state of another (like cognitive empathy), and those that respond to it (like affective empathy or empathic distress). Additionally, research makes the case that, sometimes, actions we take after witnessing others' distress are ultimately aimed at relieving our own discomfort due to experiencing affective empathy or empathic distress (Eisenberg & Eggum, 2009). This, too, is notable in the context of our work, which aims to create conditions for self-identification between user, actor, and health message and we return to this thought in the conclusion.

We are aware that empathy, in its current framing, is a relatively new construct. See, for example, Davis (2023, particularly pp. 1–14) for a poignant discussion about the modern evolution of empathy and its ties to coloniality and XR; specifically, how empathy can be read as a colonial tactic to rid guilt on behalf of the end user while continuing to place the Other in a subjugated position. We are similarly aware that attempts to define empathy have a longstanding and ongoing history in psychology. Therefore, our work is less concerned with finding the correct definition, and more engaged with discovering the connections between XR and the multifaceted components of empathy. Specifically, through a detailed "research through design" process we aim to recognize and dismantle the operationalization of various facets of empathy in XR media so that we may propose alternate and, hopefully, more just means for re-assembling them together again.

The idea of inducing or experiencing empathy through XR media broadly refers to the possibility of a user embodying another being and perspective by being technologically positioned in their place. The logic goes that this (dis)placement translates into a shared feeling and understanding. While some research does exist to support the notion of a shared feeling between self and virtual avatar through, for example, the Proteus effect (Yee et al., 2009), the notion of a shared understanding is trickier: "In suggesting that VR provides access to others' embodied experiences, it devalues the very bodies (and their situated knowledges) that are the subjects of empathy experiences" (Messeri, 2024, p. 107); furthermore, there is a "sharp edge between the intersectional politics of embodied knowledge and their co-optation" (Messeri, 2024, p. 107).

Subsequently, the construct of empathy through XR has received some well-grounded critique in its expansion into empathy culture, or what Davis (2023) describes as "the culture of workshops, self-help books, TED talks, and lesson plans to make everyone more empathetic without doing the work of modelling goodness, humanness, compassion, or caring" (p. 1). In empathy culture, argues Davis, "change and action stop being necessary…because the feeling and sense of understanding are action enough" (p. 2).

Indeed, the role of pre-structured feeling or affect has been studied extensively across diverse contexts, from education (López-Faican & Jaen, 2023) to protest movements (Jasper, 2008). In the context of communication and media studies, research often examines how affect is mediated and mobilized for specific ends (S. Ahmed, 2004; Papacharissi, 2015). Of particular interest to us is the growing body of work that critiques how affect is rallied—or at least the logic through which it is intended to be rallied—via XR media to create a sense of connection with the Other. This research often engages with the framing and operationalization of empathy through XR media and examines how such media products contribute to the problematic notion of empathy culture (Nakamura, 2020). We take these critiques as our starting point to explore what alternatives are possible. However, prior to discussing alternative ways of thinking about empathy and affect, it is worth examining in some more depth the troubling logics of affect as it translates into empathy when evoked through some XR media.

It is worth inserting here that a quick Google Scholar search in early 2024 reveals that there are almost four times as many publications on "VR and empathy" compared to "AR and empathy," even though AR is the more widely used medium. As such, there is a need to better understand the colorful dimensions of AR experiences not only in terms of their prescribed affordances by designers, but also in their realized uses by various groups of people. In turn, we analyze the logics of empathy in VR, the medium that has received primary analytical attention, and think about ways that AR media may be structured to evoke empathic responses in more ethical ways.

For empathy to occur in a VR environment, one often must virtually enter the space of and/or embody an Other through an avatar. Yet, for the original Other to become embodiable, they must be hollowed out and objectified, both practically and conceptually, so they can be mediated (Irom, 2018). A similar logic applies to the Other's spatial context. As such, "there is a risk of erasing this other such that the machine to make us more human comes at the expense of another's dehumanization" (Messeri, 2024, p. 106).

Although often with good intent, the ethics behind such media-making practices cause concern and they are often accompanied by a sleuth of others. For instance, the Other that is being embodied is typically in significantly worse-off socio-economic circumstances. It is very rare to come across an XR empathy media experience in which the user embodies and empathizes with a socially and financially better-off person (Davis, 2023; Messeri, 2024), which means that politics of privilege come into play. Further, the embodied Other is often in a far-removed social, geographical, and sometimes temporal context whereby the end goal of many VR experiences is for the user to feel affected, an emotion, toward their circumstance—not necessarily to take action. Notably, this burden of feeling is often placed on an individual user level.

Subsequently, these notions are underpinned by the Californian ideology (Barbrook & Cameron, 1996) and "the ontology that technology…as a labor-saving device…is capable of simplifying complexity" (Rouse, 2021, p. 4)—even at this intricate socio-cultural and historical level. By framing empathy as an involuntary response, its fix can also become quick, involuntary, and outsourced to technology—that is, outside of the direct scope of responsibility of human work. Yet, Rouse (2021) also argues that there is "an interesting middle space, a third possibility, between human dialogue and media simulation….This blended space may provide the most fertile ground for experimentation in the work of socially engaged immersive design moving forward" (p. 14). To be sure, we are not arguing that all XR empathy experiences are inherently problematic, but we do think that AR, as a medium, has unique characteristics that allow for a different operationalization of empathy and that need to be carefully parsed out and strategically designed for. So, we take the above problematic and well-critiqued assumptions inherent to much "empathetic" VR content as our starting point for thinking about the types of empathic conditions we wish to create in our work and to see in future AR media developments.

Specifically, we propose:

1. To design AR campaigns that are co-created with the community they are intended for. In addition, we use humor and positive framing.
2. To minimize distance between the user and Other by making content as relevant and relatable as possible. This is in sharp contrast to isolating users from their surrounding context in order to transport them to distant, de-contextualized places. In turn, the surroundings and local context become a part of the content and meaning-making process underpinning AR and help foster critical reflection of one's current place and positioning. As Messeri (2024) argues, "tech is always local, but some locations come to matter more than others" (p. 30); in our case, we want our user's location to be of primacy in their AR-mediated experience.
3. To foster active recognition of the self within the mediated space. Furthermore, to encourage users to consider taking action as opposed to remaining at the level of imagining what another is feeling and empathizing with their condition. In the context of our campaigns, this means vaccination against Covid-19 or influenza, and since both are highly infectious diseases, vaccination becomes an act of helping others, too.
4. To appeal at the level of family and community—not isolated individuals—and to do so in several ways, including through the design and dissemination of the campaigns.

Each of these points will be discussed in more detail through the annotated portfolio as part of a "research through design" approach. Next, we outline our three innovative and community co-created health campaigns, as well as our analytical process of annotated portfolios.

2. Methodology

This article analyzes three iterative and community co-created AR campaigns that aim to inform and influence parents and guardians to vaccinate their child(ren) against influenza (flu) and Covid-19 (initial vaccinations and booster series). The goal of all three campaigns was to use AR technology in what is a novel approach to increase pediatric Covid-19 and flu vaccination in majority-Black communities in West Philadelphia—populations that were disproportionately impacted by the pandemic and experienced inequitable access to the Covid-19 vaccine. To do this, we co-created AR posters and postcards with community members that were displayed around West Philadelphia. We created multiple AR posters/postcards per campaign, which we placed in different areas and tested separately to compare responses. See the Supplementary File for a timetable detailing key phases of our community co-created work.

When users scanned a QR code with their phone, the poster/postcard would come to life with an actor(s) delivering a short message about the importance of pediatric vaccination for either Covid-19 or the flu. More specifically, the video content would be emplaced over the poster as though it was a large video-screen in the user's environment. After the video, users were able to see a map, based on their location, of the closest vaccination clinics. Those accessing the influenza posters/postcards were also able to see a bank of facts about the virus, an informational video about common questions, and an interactive game. Visually drawing inspiration from the well-known Pokémon AR game, our game included an animated cartoon of the flu virus that would symbolically float around the user's environment, and one could beat it by correctly answering flu questions. To access this content, readers can scan the QR codes in Figures 1 and 2.

The community was actively involved throughout the various stages of the campaign development and deployment; a process we discuss in more detail under the "People" section of our annotated portfolio (Section 3.1). Across the three campaigns, our team collected surveys (150), focus groups (10), and anonymous, automated data about user engagement with the AR content every time the QR code was scanned. Since it is not the goal of this article to go into an analysis of our data, we next lay out how we will approach the reflection on our campaign creation process.

The concept of "research through design" is an attempt to engage systematically and reflexively with the process of creating media, technology, or other artifacts (W. Gaver, 2012; Zimmerman & Forlizzi, 2014). This approach values the co-creation of knowledge through practice and in synergy with theory, without necessarily prioritizing the latter. Key to research through design is reflexivity, iterative work, and the making explicit of implicit or tacit practices embedded in the work of designers and researchers.

Annotated portfolios are one practical means for conducting research through design (Harley, 2023), while at the same time structuring an artifact's analysis. Annotated portfolios may serve as a valuable and systematic "alternative to more formalized theory in conceptual development and practical guidance for design" (B. Gaver & Bowers, 2012, p. 44). Indeed, they are particularly useful in more formative stages of projects, where design is a key part of the research deliverable. While community-based interventions to encourage vaccinations, including for Covid-19, have been documented in several rapid reviews (Dada et al., 2022; Demeke et al., 2023), to the best of our knowledge no campaign or systematic research exist for studying the community co-creation of AR health messaging. In turn, the design process was an important aspect—the central aspect—of our work not only because it was the purview of several of our team members, but also because we wanted to tread this new ground creatively, critically, and ethically.

An annotated portfolio approach to analyzing design choices requires systematic notes and reflections across connected projects. We apply this approach by considering the people, functionality, aesthetics, practicalities, and socio-political concerns across a synthesis of our three campaigns (B. Gaver & Bowers, 2012) in conjunction with the concept of technological affordances (Gibson, 1977). We supplement our team's debriefs and project workflow analyses with some reflections from our focus groups, surveys, and back-end data. This approach to research is political, in that it uncovers the decision-making process informing design, thus responding to the oft-met critique of black-boxed technological design (Rosenberg, 1994). Our application of the annotated portfolio as part of the "research through design" process examines our team's thinking in structuring the campaigns and provides suggestions for future research and design possibilities. Since our goal is to be descriptive, critical, and self-reflexive, we do not seek to evaluate the efficacy of our campaigns, but rather to better understand the medium of AR in relation to the fraught concept of empathy in XR media.

3. Annotated Portfolio

Figure 1 shows an example of one of our posters for the Influenza AR campaign, which was first supplemented by postcards (like the one shown in Figure 2) and then altogether substituted by them.

Figure 1. First influenza AR campaign, poster.

Figure 2. Second influenza AR campaign, postcard.

3.1. People

Our academic team, community members, and survey and focus group respondents were the indispensable backbone to our AR campaigns. We purposefully built an intersectional academic team, which comprised people with different backgrounds and skill sets: from students to technology and photography experts and scholars in anthropology, media and communication, health and nursing, and vaccine and community work. We also designed the project to involve community engagement in research (CEnR) from the outset. We adopt the definition of CEnR as a "core element of any research effort involving communities," which "requires academic members to become part of the community and community members to become part of the research team, [thereby] creating a unique working and learning environment before, during, and after the research" (S. M. Ahmed & Palermo, 2010, pp. 1383–1385). CEnR encompasses a range of models including community-based participatory research, community action research, and participatory action research. The level of community engagement can vary in intensity along a continuum from light-touch outreach to shared leadership between community and research partners (Wallerstein et al., 2020). CEnR operates on the principles of "power sharing, maintenance of equity, and flexibility in pursuing goals, methods, and time frames to fit the priorities, needs, and capacities within the cultural context of communities" (S. M. Ahmed & Palermo, 2010, p. 1385).

We involved community members throughout the five stages of the campaign development process (see the Supplementary File for a detailed timetable of our work):

1. We analyzed community interviews conducted from our team members' ongoing, separate research about pediatric vaccinations, formed an adult community advisory board, and consulted with a youth group about vaccination.
2. The research from Step 1 formed the foundation for our video scripts for the AR campaigns, which were initially drafted by students studying communication and were then edited by the larger study team.
3. The edited scripts were workshopped with the community advisory board comprising local parents and guardians, to ensure that the content and context of the posters were well suited for the target community.
4. The scripts were presented to local actors from our target demographic who played a key role in refining the messaging throughout the filming process.
5. The completed AR posters/postcards were tested with community members in focus groups and at community events via short interviews and surveys. Community members received incentives for participation.

To be inclusive of our community participants, our project was open to malleability in content and timing. We scheduled community meetings around times and places that were convenient for the advisory members and sometimes moved focus groups online so mothers who did not have childcare could participate from home. This resulted in logistical challenges for our study team and, at times, a lack of consistency in our staffing, which was felt in the quantity and quality of the feedback we were receiving. It became clear that we needed to channel the community atmosphere internally that we wished to tap into externally. The concept was also evoked in several other ways. For example, parents, guardians, and youth frequently spoke not only about their responses to the AR materials but also about how they imagined their extended family members, of various ages, would respond to the materials. The imagined presence of family and community mediated users' AR experiences and sense-making, thus becoming a part of AR's infrastructure. Subsequently, we designed our second campaign (influenza) to have multiple actors of different ages and to include elements that could appeal to various age groups (the game being targeted at younger audiences, whereas the fact bank and informational video were geared toward older adults). In short, we strategically shifted our focus from one-to-one appeals to evoking multiple generations via an extended family and community unit.

3.2. Functionality

To explore our campaigns' functionalities, we draw from Gibson's (1977) notion of affordances to examine how the technical capabilities of AR can create conditions for empathetic engagement and affective responses. The affordances described below can be divided into two types: technical affordances, which are the capacities of the system, and perceived affordances, which are the actions users believe they can take and the emotional responses they might experience.

The main technical affordances of AR include web functionality, tracking, registration, interaction, and display. *Web functionality* meant that our application ran completely from the web on WebXR standards, requiring no user downloads. Furthermore, it meant that we could update it on the fly by using backend-hosted servers from Glitch (https://glitch.com). This ease of access lowered barriers to engagement, allowing for a more immediate connection with the content. *Tracking*, the ability to monitor the user's position and orientation in real-time, enabled accurate placement of virtual content within the user's environment. This capability, combined with *registration* (the alignment of virtual content with real-world objects), created an integration between the virtual and real (Azuma, 1997) that could evoke a sense of presence and immediacy. We leveraged these affordances in our Pokémon-inspired game, where an animated cartoon flu virus floats on the screen around the user's environment. *Interaction*, the ability to manipulate virtual content using various input methods such as touch and gesture, offered users a sense of agency within the AR experience. Furthermore, the gamification of health information aimed to deepen users' engagement and emotional investment in the content. *Display*, the visual presentation of virtual content alongside the physical environment, allowed us to create a hybrid space where interaction would take place between user and content. The content was designed to contain familiar app and gameplay elements and modes of interaction to create a comfortable and engaging interface that could help users easily navigate the information presented.

Perceived affordances are shaped by users' past experiences and socio-cultural backgrounds (Norman, 1999). In our case, while community members were familiar with QR codes, they had never seen a poster or postcard "come to life" or played an AR game in this context. This element of surprise and novelty became a generative aspect of our campaigns. Users often expressed delight at seeing the poster animate and the flu virus float around their environment. This created a personal and emotionally engaging experience that often encouraged our participants to pay attention to vaccination messaging they might otherwise not be inclined to hear. One parent shared that when you feel like someone *like* you is talking *to* you, it is harder to tune out than regular text or video.

The interplay between technical and perceived affordances in our AR campaigns, particularly in video content and the Pokémon-inspired game, created opportunities for what we might call "empathetic moments"—instances where the technology's capabilities aligned with users' perceptions to create conditions conducive to emotional engagement and, potentially, empathetic responses to the health messaging. By making the invisible visible through the floating flu virus, and by allowing users to actively engage with health information through gameplay, we aimed to create a more visceral and emotionally resonant understanding of the importance of flu vaccination.

This approach to functionality demonstrates how AR can be leveraged not just as a technological tool, but as a medium for creating affective experiences that have the potential to foster connection and understanding around important health—or other—issues. However, despite the potential of AR's affordances to create engaging and empathetic experiences, it is important to acknowledge their limitations. The effectiveness of tracking and registration can be compromised by environmental factors such as lighting conditions or complex physical spaces, potentially disrupting the seamless integration of virtual and real elements. Although we used WebXR standards compliant with A-Frame, we did find that newer/older phones and Android/Apple phones behaved differently, which sometimes resulted in varying issues for users (e.g., loading times, frame rates, etc.). Moreover, the novelty of AR interactions may wear off over time, potentially diminishing their emotional appeal and ability to foster empathetic engagement in long-term or repeated-use scenarios.

3.3. Aesthetics

We placed heavy emphasis on authentic representation in our videos: Our actors were all accomplished professionals who were also local to the Philadelphia area and many of them were parents and guardians themselves. This approach aligns with the Centers for Disease Control and Prevention's (2021) recommendation for disseminating information about vaccines via trusted messengers. In short, families are more willing to accept vaccine information if "you look like me…or if it's coming from someone that is from here" (Summers et al., 2023, p. 5). For us, this step was key in creating conditions for self-identification and empathy. Indeed, many of our focus group respondents perceived and appreciated the likeness of the characters.

Following community feedback, we also opted for less formal-looking campaigns, although some of our team members thought we could have gone further in that direction. For example, we adopted more informal language and opted for less text on subsequent versions of our posters (and even less on our postcards). We also encouraged our actors to improvise parts of the scripts, which made the videos significantly more relatable and entertaining, and included elements like our actors breaking the fourth wall by addressing the user directly through the screen through "Hey, you!" Figures 3 and 4 are examples of how

MISSING HOLIDAY DINNER

INT. BEDROOM – DAY

Actors: Mom (20-40's wearing pajamas, looking very ill), Junior (8-10, wearing pajamas, looking very ill) Dad (off camera)

Props:

- Bed
- Blankets
- Pillows
- Tissues
- Thermometer
- Ice pack
- Broom stick
- Bucket
- Rice crackers

Scene: Mom and Junior are both sitting up in bed. Mom has her arm around his shoulder, he's laying up against her looking miserable. The bed is covered with tissue boxes and used tissues.

Mom: Fall is my favorite time of year. My whole family gets together, I make my special pie, my auntie makes her amazing greens. Everybody has fun. Hear them? This year Junior got the flu at school. In September! And now I'm sick. And he's sick. And the rest of the family is having a great time without us. Can you hear them? I didn't know flu season started so early. And I didn't realize that getting vaccinated reduces your chances of catching the flu by XYZ, or that you can get vaccinated for free at Philadelphia City Clinics if you don't have insurance.

Junior: I'm hungry. Do you think they forgot about us?

From off camera comes a pole with a bucket on the end of it. Mom reaches into the bucket and pulls out a packet of rice crackers..

Mom: Oh look, rice crackers. (Hands the rice crackers to Junior and calls out in the direction the pole came from) Thank you honey! Can you bring us more tissues?

Figure 3. Original script for *Missing Holiday Dinner*, August 10, 2023.

SCRIPT 1: MISSING HOLIDAY DINNER
INT. BEDROOM – DAY
Actors: Mom (20-40's wearing pajamas, looking very ill), Child (8-16, wearing pajamas, looking very ill) Dad (off camera)

Props:
- Bed
- Blankets
- Pillows
- Tissues
    - 10-20 Tissue boxes (exaggerate to make it look funny)
- Thermometer
- Ice pack
- Broom stick
- Bucket
- Rice crackers
- Teddy bear

Scene: Mom and Junior are both sitting up in bed. Mom has her arm around his shoulder, he's laying up against her looking miserable, clutching a teddy bear. 10-20 Tissue boxes surround them.

Mom: Fall is my favorite time of year. My whole family gets together, I make my special pie, my auntie makes her amazing greens. Everybody has fun. Hear them? [pause for sound of joy coming from the other room]

This year Junior (change name since our actor is female?) got the flu at school. In September! And now I'm sick. And she's sick. And the rest of the family is having a great time without us. ~~Can you hear them?~~ Turns out flu season starts as early as August but you can reduce your child's chances of catching the flu by getting them vaccinated. And you can do it for free at Philadelphia City Clinics.

Child (sounding miserable): I'm hungry. Do you think they forgot about us?

From off camera comes a pole with a bucket on the end of it. Mom reaches into the bucket and pulls out a packet of rice crackers..

Mom: Oh look, rice crackers. (Hands the rice crackers to Junior and calls out in the direction the pole came from) Thank you honey! Can you bring us more tissues?

Figure 4. Final version of the script for *Missing Holiday Dinner*, August 24, 2023.

our first influenza script evolved, and readers can see the final version, with additional actor improvisation, by scanning the QR code in Figure 1. Based on feedback, one notable difference between the first and final script versions was our positive and empowering reframing of the parent's engagement with the virus; the parent went from not knowing much about influenza in the first version of the script to delivering an informed yet casual message about the vaccination in the latter versions.

In addition, we opted for humor and a lighthearted aesthetic throughout our scripts in contrast to the more often encountered "serious" style of community health messaging. Research shows that humor is well-perceived in youth and pediatric vaccination messaging, especially amongst populations that are hesitant toward the messaging and messenger (Moyer-Gusé et al., 2018; Yoon et al., 2023). The videos were also all filmed in Philadelphia within close proximity to their target audience, though the majority were filmed indoors due to better control over lighting and sound (see Figure 5). Unfortunately, through focus groups, it became clear that these authentic locative features were not always readily apparent; although, when they were, they did make a significant positive difference in the perception of the content. In the

Figure 5. Photograph of AR filming.

future, we would benefit from further integrating local, recognizable outdoor landscapes within our AR work and, per parent suggestions, including local soundscapes or music.

In several of the videos, our actors play the role of a doctor or nurse without uniform, and this, too, raised some credibility concerns over whether these were real medical professionals. (Notably, the videos where parents addressed viewers seemed to be better received than when “professionals” delivered the same message.) We also initially chose Zappar (https://www.zappar.com) to host and display our AR content, which required numerous clicks on behalf of the user to grant access to various features. In subsequent campaigns, we developed and coded a no-download HTML5 WebXR solution hosted on Glitch, which allowed for one-click content access through the QR code. Although the Glitch server proved to be a reliable and free web host, the name “glitch.com” appeared in the browser address bar on participants’ phones and, given the name, raised some questions about the reliability of the link.

Indeed, our audiences seemed sensitive to the authenticity of the digital content, prompting us to think about how we might address the broader topic of content verification that is currently prevailing across the media sector. Further, as the above paragraphs demonstrate, we faced the constant tension of the balancing act of creating an authentic, community co-created campaign that was simultaneously perceived as authoritative and trustworthy given the gravity of the medical context.

3.4. Practicalities

While posters/postcards “coming to life” through the scanning of a QR code was a new technological experience for most, it took place on a familiar device, their phone. We received feedback from community members wishing to have the flexibility to take the AR experience with them and see it during their own free time (as well as to easily share it with others), so we were able to pivot from a poster-only first campaign to a postcard-supplemented and then postcard-only second and third campaigns. To make the content accessible, we also created closed captions for all videos.

Despite testing on a variety of phones and operating systems, the self-administered AR experiences did not always work for everyone. This prompted our team to wonder what information we could still offer those who were not able to access any of the AR features. This is partially why our posters/postcards have some text; although, as previously noted, this decreased with time. Lastly, this series of campaigns was created as an ongoing proof of concept; however, the sustainability of such projects is important and includes addressing issues of content hosting and archiving.

3.5. Socio-Political Concerns

Vaccination messaging, specifically around Covid-19 and the optional influenza vaccine, is itself a politically fraught topic. Many of the community members we spoke with, across various age groups, shared historically rooted concerns over these vaccinations. As noted earlier, while almost everyone we showed our materials to stated they enjoyed interacting with the AR, as expected, not everyone was convinced by the vaccination messaging (see Figure 6 of community showcase event soliciting feedback and celebrating work).

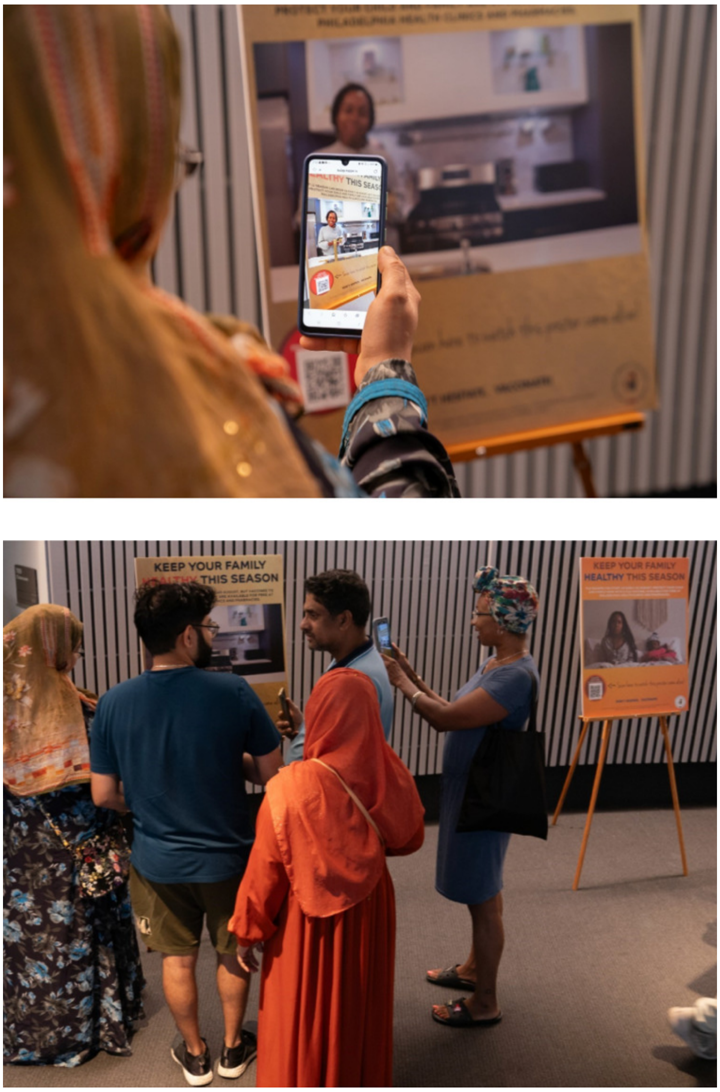

Figure 6. Photographs from the community showcase event.

We also received some community feedback about a lack of a recognizable logo. This was a decision our team came to because there exist historical tensions between the University, which is based in West Philadelphia, and the neighboring communities. In turn, we thought using the University logo could lead to negative associations with the campaigns and we decided to use a more neutral emblem. The downside of this choice was that the logo was largely unrecognizable and perceived as less credible by our participants.

Lastly, our very reflections on this series of campaigns are a conscious attempt to open the oft-called black box of technology and the decision-making that goes into its creation. Furthermore, as mothers of color are underrepresented in research in general (Sealy-Jefferson, 2022), this encouraged us to utilize flexible methodologies for engagement with the hope that our research is one step toward greater inclusivity—a point we shared in our interactions with community members and one that was well received.

4. Conclusion

This piece adopted a "research through design" approach to examine the process of co-creating three AR campaigns with community members. By critically reflecting upon our campaign designs, we interrogate how the making and consumption of AR becomes a cultural practice, embedded within local spaces and actors. Specifically, we pose that community was an integral part of the socio-technical infrastructure of our AR campaigns as it structured our design choices and mediated users' experiences. When seen as such, a community focus can lead to different types of operationalizations of empathy.

Deep localization allowed us to minimize the distance between the user and the AR Other, and it helped to foster critical reflection of one's current place and positioning in relation to the health messaging. We did not want users just to imagine what the actors in the video were feeling regarding vaccination. To return to Batson's (2009) types of empathy, that would mean remaining at a perceptive level. Rather, we wanted users to see themselves within the scenarios and to move toward a state of responsive empathy and action. In this sense, we were also appealing to the theory that, often, action based on empathy aims to assuage discomfort felt by the empathizer, with positive effects for the one being empathized with as a secondary benefit. Indeed, in our context, action on behalf of the user (considering or getting their child vaccinated) benefits the community too. Therefore, we view self-identification through deep localization and the multifaceted concept of empathy in productive interplay.

Furthermore, the annotation of our AR campaigns presents a pushback against the idea that empathy should be "understood as an almost involuntary emotional response" (Rouse, 2021, p. 5) that does not require any work. Instead, through a slower process centered on dialogue, meaningful community relations, and co-design, we reveal that empathic responses require analytical work on behalf of audiences, who often use the lens of community and authenticity to evaluate their responses and can be aided or hindered through certain design choices that impact these two dimensions. Early findings indicate that the more credible, community-oriented, and relatable the AR content, the more likely users were to feel a connection with it and to be able to critically place themselves within the scenario. Thus, in synergy with AR technology, affect through humor and emotional familial appeals have the potential to be channeled into an ongoing, collaborative process of reflection anchored in community knowledge and spaces. We see an opportunity for future research to explore this emerging affective economy (S. Ahmed, 2004; Messeri, 2024); that is, the dynamics between the multiple forces resulting in the cumulative product of "affect" and self-identification/empathy.

The recurring theme of community was present throughout the iterative stages of our AR work: from our campaign's process of localized, community co-development, to the subsequent functionality updates enabled by flexible A-frame WebXR technologies, and our users' references to community in their sense-making practices of the AR content. Thus, we synthesize the overarching function of community into what we call empathic feedback loops. In contrast to many XR applications that overlook community contexts and provide decontextualized, vague user feedback to the designers and users, we sought to contextualize our community feedback as much as possible.

Can the design of this AR campaign translate to other contexts and to XR content more broadly? While there are context-specific challenges and issues associated with scale, we argue the design of our campaign can be replicated as long as some key conditions are met. It is important for users to be able to recognize their own lived realities and cultural contexts reflected in the AR content *and* for it to be embedded within their social fabrics. This allows for more personal, ethical, and potentially empathic connections to the content and occurs best when potential users are involved in the design. Through this work, our team saw firsthand the intricate level of physical, contextual cues that underpin meaning-making processes in the medium of AR. Subsequently, we see potential to extend our work through mixed reality applications, which currently present a prominent avenue of industry development. Additionally, it would be insightful to test whether the ideas we developed for AR can be successfully incorporated back into VR to alleviate some of the critiques that inspired this piece.

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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ARTICLE

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Understanding Expressions of Self-Determination Theory in the Evaluation of IDEA-Themed VR Storytelling

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Abstract

This study investigates how prior experiences (personal or a close other's) influence individuals' engagement with virtual reality (VR) stories designed to promote understanding and foster prosocial behavior. Integrating self-determination theory and self–other overlap, we conducted an experimental mixed-method study with 35 participants who experienced three VR stories focused on inclusion, diversity, equity, and accessibility (IDEA): living with Alzheimer's, blindness, and in a refugee camp. Findings indicate that while participants felt some autonomy with the VR headset, they experienced a lack of autonomy, competence, and relatedness in the storytelling. Participants engaged in perspective-taking but often thought about those close to them who had similar experiences rather than themselves. Thus, a close other's experience affected whether people engaged in perspective-taking. However, prior experience with IDEA topics did not predict cognitive effort, indicating that individuals with such experience do not exert more cognitive effort than those without it. Additionally, cognitive effort did not predict prosocial attitudes or behaviors. This study highlights the complexities of how previous experiences affect engagement with IDEA-centered VR, perspective-taking, and cognitive effort and suggests directions for future research.

Keywords

diversity; equity; self-determination theory; self-other overlap; virtual reality

1. Introduction

Virtual reality (VR) technology has become an influential tool for creating immersive and engaging experiences across various domains, including education, training, therapy, and entertainment. As VR continues to evolve, there is a growing emphasis on designing content centered on inclusive, diverse, equitable, and accessible (IDEA) concepts (see Indiana Arts Commission, 2018; Krombolz, 2021). IDEA-centered content, whether designed for or adapted for VR, often features experiences of social plight. For example, VR content features people's experiences with racism (Brown, 2018), homelessness (Ogle et al., 2018), blindness (Colinart et al., 2016), and living with Alzheimer's (*The New York Times*, 2018). The expectation is that VR can "encourage empathy for understanding and addressing structural inequalities, VR can be used to simulate situations that people from marginalized groups face in the real world, such as discrimination or bias" (Richter et al., 2023, p. 575).

The immersive nature of VR has been found to elicit a greater sense of presence (or "being there") and engagement with the virtual environment than is produced by other types of media formats. This heightened experience can increase emotional engagement and attention (Cummings & Bailenson, 2016) and potentially empathy (Martingano et al., 2021). Indeed, VR is sometimes referred to as a mechanism that can evoke the ability to understand a situation (i.e., empathy) or as an "empathy machine" (Milk, 2015), although research on these effects has sometimes produced mixed results. Studies suggest that VR may be more effective in improving emotional empathy (compassionate feelings) than in enhancing cognitive empathy or perspective-taking (see Martingano et al., 2021).

Martingano et al. (2021) suggest that cognitive empathy requires "effortful mentalizing." In examining the ways that VR narratives impact perspective-taking, it is therefore important to consider the motivational and experiential factors that can impact this process. From a self-determination theory (SDT) perspective (Deci & Ryan, 1985, 2000), people's motivations to engage in the effortful mentalizing required by perspective-taking may be impacted by their ability to understand and navigate a VR experience (competence), their sense of agency or autonomy in the situation, and their sense of relatedness to those featured in the VR IDEA narrative. A key factor in the process may be users' prior experience. This can impact users' ability to imagine being in another person's situation and to understand their social plight (Batson & Ahmad, 2009). In addition, knowing a close other who has experienced social plight not only makes people more aware of those struggles, but also predicts empathetic attitudes to other's situations (Batson et al., 1997). Therefore, having experience or a close other experience may be a factor in cognitive empathy (i.e., perspective-taking). Conceptually, if the experience elicits a reminder of one's personal experience or a close other, it may evoke feelings of competence, autonomy, or relatedness and ease of perspective-taking. Alternatively, prior experiences (self or other) may evoke cognitive overload and be a negative reminder of a close other, creating the opposite desired effect of eliciting intrinsic motivation. In other words, participants may feel like they lack control of the situation (e.g., cannot help), have no agency over their actions in the experience, and feel a lack of belonging or relatedness due to the struggles based on prior experiences. If the IDEA-themed VR content is too cognitively taxing, people will not want to engage with it further. In the present study, we integrate self–other overlap and SDT to explore how IDEA-centered VR experiences elicit conversations of prior experience, perspective-taking, and components of SDT. Additionally, we examine how prior experience relates to cognitive effort.

2. Literature Review

2.1. Perspective-Taking and Cognitive Effort in VR

VR possesses unique features that make it exceptionally well-suited for studying empathy. By immersing users in fully interactive and three-dimensional environments, VR can simulate real-life experiences with a high degree of realism (Slater & Sanchez-Vives, 2016). This immersive quality allows individuals to step into someone else's shoes and experience scenarios from different perspectives, fostering a deeper understanding and emotional connection to others' experiences (Ahn et al., 2013). Mass Communication researchers (e.g., Pan & Hamilton, 2018; Schutte & Stilinović, 2017; Ventura et al., 2020) have found that VR's capacity for creating controlled and repeatable environments is well-suited for systematically manipulating variables and observing their effects on empathetic responses.

Putting on a VR headset can mean putting oneself into another's shoes by engaging in a real-life simulated environment, experiencing the narrative of the content, and eliciting thoughts and emotions from those experiences. VR content, particularly IDEA-focused content, allows users to understand the perspectives of others' struggles, therefore it is understandable there is extensive research investigating VR and perspective-taking. Perspective-taking or cognitive empathy is the ability to understand another's point of view and to understand how someone else thinks or feels about a situation (Herrera et al., 2018; Singer & Fehr, 2005). Findings have shown that perspective-taking can be evoked with VR. For example, after engaging in a VR experience that offered first-person perspectives of a racial minority experiencing racial discrimination, people reported that VR increased their empathy (e.g., cognitive and emotional) toward racial minorities (Nikolaou et al., 2022; Roswell et al., 2020). As noted earlier, however, findings on perspective-taking through VR are not definitive. In their meta-analysis of VR and empathy studies, Martingano et al. (2021) argue that thinking about others' perspectives requires deliberate cognitive effort.

Cognitive effort refers to the mental resources and processing demands required to interact with new stimuli in an environment (Tyler et al., 1979). Although the wealth of detail available in immersive narratives can enhance users' sense of presence, it is also possible that it may require greater effort to sift through relevant elements and to understand VR narratives. It has been noted that people are cognitive misers and averse to expending cognitive effort (Wu et al., 2023). Studies have found that people are aversive to exerting cognitive effort even when offered a monetary reward (Depow et al., 2022). That said, since too much cognitive exertion may negatively impact people's engagement (Bueno-Vesga et al., 2021), people are even more reluctant when those efforts are directed towards benefiting strangers, including charities that hold personal significance to them (Depow et al., 2022). This shift in focus highlights the nuanced relationship between prior experiences and empathetic understanding.

2.2. Prior Experience and Perspective-Taking

Thinking about relative experiences may make it easier to cognitively and affectively understand someone else's experiences. As argued by Preston and Hofelich (2012), people need an anchor to engage in empathy, "When the observer really does not have any related experience with the situation, he/she cannot empathize through passive activation of shared representations" (p. 28). Therefore, finding similarities from one's prior experience may not only be a bridge to empathy but also a factor in cognitive effort. Like prior exposure to a stimulus predicts the ease and fluency of which it is later processed, prior experiences may make it easier to empathize with people encountering an analogous event cognitively. For example, people who perceive another's situation as similar to their past experiences and reflect more deeply on similar past experiences find it easier to understand another's perspective (Gerace et al., 2013, 2015).

Therefore, identifying similarities from one's previous experiences may not only serve as a pathway to empathy but could also play a role in cognitive effort. Just as familiarity with a stimulus can predict the ease with which it is later processed, past experiences could potentially ease the process of empathizing cognitively with individuals facing similar situations. For instance, individuals who view another's circumstances as reminiscent of their own past experiences and who reflect more profoundly on these analogous past experiences find it simpler to comprehend another's viewpoint (Gerace et al., 2013, 2015). However, considering that social plight can be a traumatic experience, VR experiences that feature social plight can serve as a reminder of that experience, thus increasing one's cognitive effort. Therefore, it is unclear whether one's prior experience will increase or decrease cognitive effort. Bridging these concepts, we delve into how personal history influences our ability to connect with others.

2.3. Prior Experience and Self–Other Overlap

Interestingly, people take on others' past experiences when they are close to them. Self–other overlap is a psychological construct that assesses perceived closeness and one's feeling connected to another (Aron & Fraley, 1999). Self–other overlap posits that when we feel close to another so much, we include the other in our self. Additionally, the more self–other overlap, the more likely people are willing to help express prosocial attitudes and behaviors and engage in perspective-taking (Myers & Hodges, 2012). Therefore, self-other overlap is an excellent framework to explore how prior experience indicates perspective-taking, whether people use a close other's experience as a perspective-taking strategy, and how prior experience relates to cognitive effort. In examining perspective-taking strategies, the integration of SDT's core tenets—relatedness, autonomy, and competence—emerges as a nuanced factor in the discourse.

2.4. SDT

Correspondingly, SDT (Deci & Ryan, 1985, 2000) is a framework often applied to motivation studies that distinguish whether people are motivated to engage with a task by their volition for the enjoyment of the task rather than a reward (i.e., intrinsic motivation) or engaging in a task for a reward like money or praise (i.e., extrinsic motivation). Additionally, the SDT framework explains how social and cultural factors can either bolster or undermine individuals' sense of volition, well-being, and performance quality. Components of SDT include autonomy, relatedness, and competence.

Relatedness refers to the inherent desire to feel connected to others, belong, and experience meaningful relationships within one's social environment (Deci & Ryan, 2000). Relatedness is crucial for fostering intrinsic motivation, as it provides individuals with a sense of social support and validation, which can positively impact their engagement, making it a significant factor in designing and implementing IDEA-focused VR content. Competency relates to feeling like one has the skills to effectively engage in one's environment (Ryan & Deci, 2002). Lastly, autonomy involves having a sense of agency or control over one's actions. When individuals are autonomous, they perceive their actions as true expressions of themselves; thus, even when external factors shape their actions, they align with these influences, feeling both a sense of initiative and value (Ryan & Deci, 2002). Moreover, SDT posits that individuals have intrinsic needs for autonomy, competence, and relatedness, which drive their motivation and behavior (Deci & Ryan, 1985). When these needs are supported, individuals experience greater intrinsic motivation, enhancing engagement, performance, and well-being (Ryan & Deci, 2002).

In VR, SDT offers a valuable framework for understanding how users' psychological needs influence their engagement in immersive experiences. Previous studies have demonstrated the impact of intrinsic motivation across various VR applications. For example, studies have suggested that VR can enhance users' autonomy (Ijaz et al., 2020; Kosa et al., 2020), and competence (Kosa et al., 2020), increasing gaming enjoyment. In educational settings, experiences of autonomy and relatedness in VR have been positively associated with intrinsic motivation for learning (Huang et al., 2019). Additionally, findings suggest that teachers who perceive high levels of autonomy and competency are more likely to utilize virtual learning environments in their teaching (Hew & Kadir, 2016). In other words, people who are intrinsically motivated (i.e., having autonomy, relatedness, and competency) are more likely to engage with that task (e.g., VR) of their own volition and have an increased likelihood of doing that task in the future. Conversely, individuals may be less inclined to engage in prosocial attitudes or behavior when they feel less connected to the recipients of their help (Depow et al., 2022). Taken together, this practical application of SDT in the context of VR content and storytelling can provide valuable insights into users' likelihood of intrinsic motivation, future use, and well-being.

Taking this into account, we propose the following research questions:

> RQ1: How do participants express autonomy, competence, and relatedness among three IDEA-themed 360° VR videos?
>
> RQ2: How do prior IDEA experiences elicit VR users' perspective-taking (i.e., cognitive empathy)?
>
> RQ3: To what extent is there a relationship between prior IDEA experiences and cognitive effort?
>
> RQ4: Is there a relationship between cognitive effort and prosocial attitudes and behaviors?

3. Methods

3.1. Research Design and Participants

This experimental study employs an explanatory mixed methods design with sequential data collection to investigate how IDEA-centered VR experiences elicit conversations of prior experience, perspective-taking, and SDT. In addition, we examine how prior experience relates to cognitive effort. This design integrates quantitative survey and psychophysiological data with qualitative interview data to address our research questions.

Upon approval by the institutional review board, 35 participants were recruited from a private university in the United States using convenience and snowball sampling through flyers and word of mouth. On average, participants were 25.6 years old (*SD* = 7.45), ranging from 19 to 51. Of the participants, 34.2% (*N* = 12) identified as White, 25.7% (*N* = 9) Asian, and 14.2% (*N* = 5) Black/African-American. Approximately 48.5% (*N* = 17) identified as male, 48.5% (*N* = 17) as female, and 2.8% (*N* = 1) as transgender male. Detailed demographic information, including a full breakdown of participants' racial/ethnic identity, political orientation, and education, is presented in Table 1.

Table 1. Demographic information of participants.

Variable		*N* (%)
Age	*M* = 25.6 (*SD* = 7.45)	
Gender	Male	17 (48.5%)
	Female	17 (48.5%)
	Transgender male	1 (2.8%)
Race/Ethnicity	White	12 (34.2%)
	Asian	9 (25.7%)
	Black/African-American	5 (14.2%)
	White—Latin/Hispanic	3 (8.5%)
	Latin/Hispanic	1 (2.8%)
	White—Indian	1 (2.8%)
	White—Korean	1 (2.8%)
	Caribbean—American	1 (2.8%)
	White—Persian/Middle Eastern	1 (2.8%)
	Middle Eastern—North Africa	1 (2.8%)
Political orientation	Democrat	14 (40%)
	No preference	8 (22.8%)
	Independent closer to democrat	6 (17.1%)
	Don't know	3 (8.5%)
	Others	2 (5.7%)
	Independent closer to Republican	1 (2.8%)
	Republican	1 (2.8%)
Education	Some college but no degree	10 (28.5%)
	Master's degree	9 (25.7%)
	Bachelor's degree in college (four-year)	8 (22.8%)
	Highschool graduate	5 (14.2%)
	Associate degree in college (two-year)	2 (5.7%)
	Doctoral degree	1 (2.8%)

3.2. Procedure

This study is a part of a larger research project. The materials and procedures outlined pertain solely to what was evaluated within this specific study. Therefore, once participants entered the lab, they read the informed consent form and were instructed to complete a demographic questionnaire and a series of self-reports. Then, researchers fitted participants with the HP Reverb G2 Omnicept Edition (Omnicept) VR headset. The Omnicept VR headset displays VR experiences and measures participants' heart rate, eye tracking, and cognitive load.

Once fitted with the Omnicept VR headset, participants' baseline cognitive effort data was collected. Subsequently, participants engaged in three IDEA-themed VR experiences. After each VR experience, researchers removed the Omnicept VR headset, and participants were briefly interviewed about their experiences. Then, researchers offered participants a break before starting the next experience. This sequence repeated until participants completed all three experiences. After completing their final IDEA-themed VR experience, participants engaged in a semi-structured interview lasting approximately 15 minutes. Researchers randomized the presentation of the VR experiences to reduce order effects. The entire study took approximately one hour to complete.

3.3. VR Stimuli

We selected three 360° VR videos of similar length as stimuli. *Notes on Blindness* (Colinart et al., 2016), presented in first-person, inspired by John Hull's experiences after losing his sight in 1983, immerses users in his experience of navigating environments like parks and streets through computer-generated imagery (see Figure 1a). *Coping with Alzheimer's, Together and Apart* (hereafter *Coping with Alzheimer's*; *The New York Times*, 2017), shot in the third-person, presents how an Alzheimer's patient, Aline Zerrenner, and her husband are managing her memory loss (see Figure 1b). *My Home, Shatila* (van Apeldoorn & Tan, 2019), shot in third-person, follows Fadia, a 14-year-old Palestine-Syrian refugee living in the Shatila refugee camp in Beirut, Lebanon, presenting her challenges and her resilience (see Figure 1c). Researchers classified these VR experiences as IDEA-themed because they each showcased experiences with social plight and centered on issues of IDEA. All 360° VR videos were approximately four-and-a-half minutes long.

3.4. Measurements

Prior experience was measured using three 5-point Likert scale questions about their previous experience with Alzheimer's disease, living with blindness, or living in a refugee (e.g., "I or someone close to me has or has had exposure to refugee experiences"). In addition, researchers assessed interview responses for mentions of personal or a close other's experiences with the observed IDEA situations. Participants were not explicitly asked in interviews if they or a close other has had experience with IDEA situations. Yet, during interviews many participants chose to discuss experiences they or close others had that they felt were similar or relevant to the VR story content.

Cognitive effort is measured through the amount of mental effort being utilized to complete this experiment which is often referred to as the cognitive load (Chen et al., 2011; Sweller, 2011; Sweller & Chandler, 1991). Based on Siegel et al.'s (2021) research on the multimodal inference engine for detecting real-time mental workload, the real-time cognitive load can be effectively and reliably calculated by combining the measurement of eye tracking and pulse plethysmography via a trained machine learning model. Each of the real-time cognitive load scores is normalized to a range of [0–1].

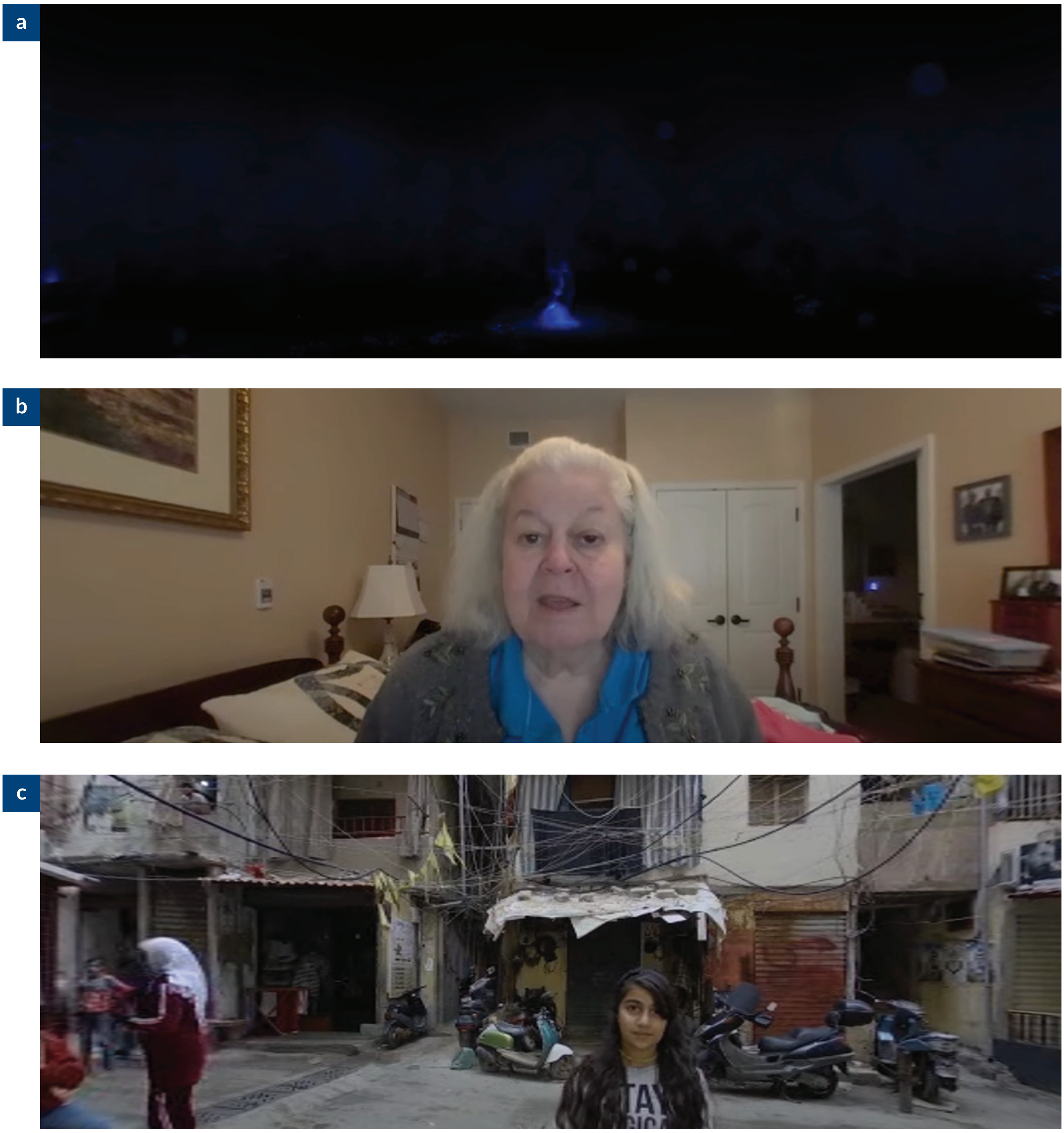

Figure 1. Example scenes of VR stimuli from: (a) *Notes on Blindness*; (b) *Coping with Alzheimer's, Together and Apart*; and (c) *My Home, Shatila*.

For this study, the Omnicept VR headset was employed to gather eye-tracking and pulse plethysmography data. These data were processed in real time by an integrated machine-learning model to calculate cognitive load scores. The real-time cognitive load scores were then displayed via the Omnicept Overlay software. All cognitive load scores were calculated using Omnicept's internally trained machine learning model. Screen capturing was conducted using OBS Studio to video record the experimental sessions with real-time sensor display information (see Figure 2). Each video was segmented into second-by-second screen captures, displaying the cognitive score for each second, which will be utilized for data analysis. Additionally, as each

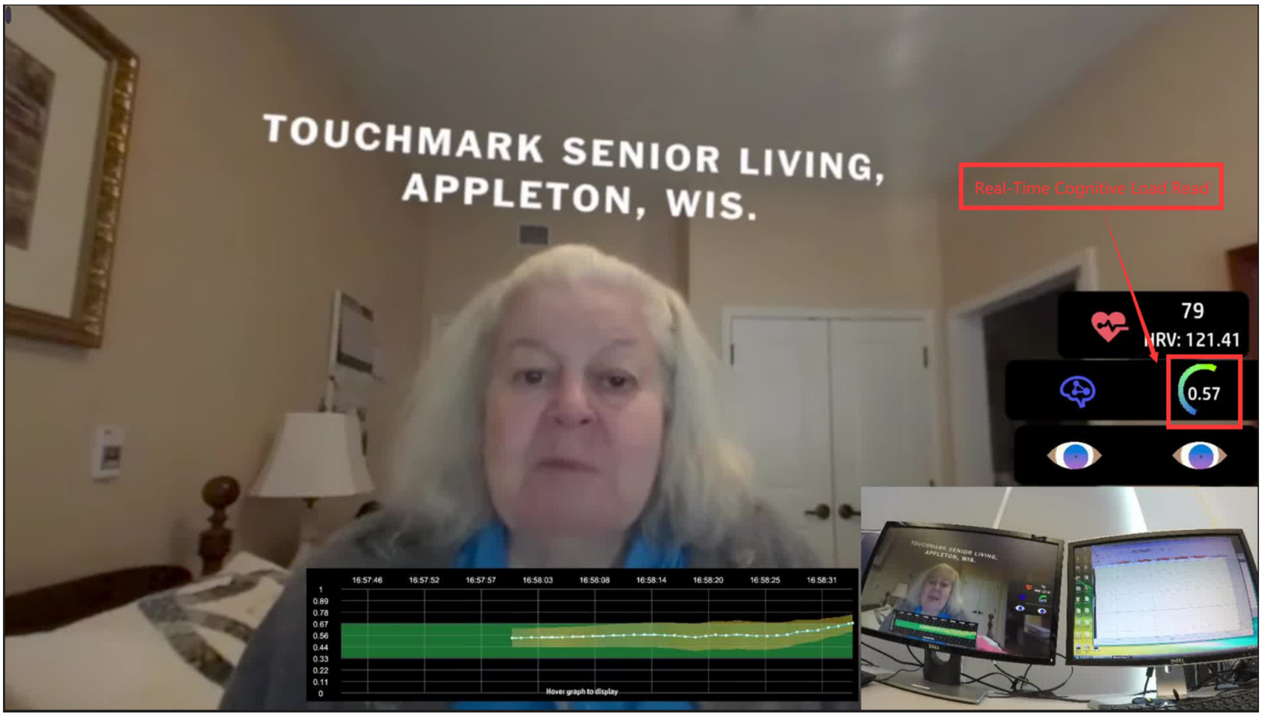

Figure 2. Real-time sensors display information on VR stimuli.

screenshot captures what the participants were viewing at any given second, the data can be further coded and analyzed in depth.

The cognitive load score from the data collection screen capture was processed and extracted using a custom-developed Python script. Text extraction from the processed images was performed using Tesseract OCR. The script extracted numerical data, which were then parsed to retain only numeric characters and decimal points. Cognitive load experienced by individuals can vary significantly (Engle & Kane, 2004; Oberauer et al., 2007). Therefore, it is not practical to directly compare cognitive load scores between subjects in this study. Instead, cognitive effort was operationalized by using the ratio of high cognitive load scores to total cognitive load scores, where a high cognitive load score indicates a greater exertion of cognitive effort. This percentage ratio represented the proportion of cognitive effort dedicated to each experience.

Each participant's baseline cognitive load score was established by calculating the mean score across the entire session. From scores exceeding this mean, a median was calculated. The total cognitive load scores above the mean were then tallied and divided by the aggregate cognitive load scores to form a cognitive effort score. This method provides a normalized measure of cognitive effort exerted during VR experiences.

3.5. Data Analyses

Quantitative variables included cognitive load scores, transformed prosocial attitudes and behaviors data, and merged prior experiences data, which researchers assessed in a series of simple linear regression analyses and a repeated analysis of variance to address RQ3 and RQ4 using Statistical Product and Service Solutions version 29.

Qualitative data consisted of 35 semi-structured interviews, including brief interviews after each IDEA-themed experience and the interview to assess each participant's overall experience. Complete interviews ranged from 9 to 36 minutes. Following Saldaña's (2015) method of thematic coding, researchers explored both latent and manifest interpretations. Using NVivo 14 software, researchers initially used open coding, applying an SDT and self–other overlap framework. After several iterations of cycles of coding, researchers refined codes into overarching themes and organized codes and subcodes into overarching themes.

To assess one's prior experience with the observed IDEA topics, researchers merged quantitative (survey items) and qualitative (interview responses) data to cross-reference one's previous experience. Additionally, to understand whether there was a relationship between cognitive effort and prosocial attitudes and behaviors, several simple linear regression coefficient test analyses were conducted to test the relationship between cognitive effort and prosocial attitudes and behavior engagement. The prosocial attitudes and behavior engagement scores were transformed from the prosocial engagement reported in interviews.

4. Results and Discussion

4.1. Qualitative Findings

Five themes emerged through the analysis of qualitative findings. First, participants felt a sense of autonomy, enjoying their ability to navigate and explore the VR environments. Second, they experienced a lack of competence and relatedness, noting that they sometimes failed to connect to the VR content or understand the stories fully. Third, some participants successfully adopted the perspectives of the VR subjects. Fourth, many participants projected their own or a close others' experiences onto the VR content rather than fully immersing themselves in the subjects' perspectives. Finally, participants reported gaining valuable insights from the VR experiences and expressed a heightened desire to be more considerate and empathetic in their everyday lives.

4.1.1. RQ1: Autonomy in Observation

In exploring how participants express autonomy, competence, and relatedness within three IDEA-themed VR experiences, the findings reveal a strong sense of autonomy but limited perceptions of competence and relatedness. Participants mentioned autonomy, a component of SDT, in relation to the medium (Omnicept VR headset) and with respect to the IDEA-themed content. Specifically, participants expressed a sense of agency using the headset. For example, participant E, a 25-year-old, described her reaction to *My Home, Shatila*, "I was like looking all over, and it really gave you a sense of what it looked like in the space and made you really feel for her and get a personal perspective on her life."

In addition, 22-year-old participant H explained his overall experience with the VR, noting how he chose to focus most on "a carousel playing" and "when people were walking" during *Notes on Blindness*. Further, Fadia's movements during *My Home, Shatila* required that viewers "choose which [elements] to focus on." Participants felt a notable degree of agency and control while interacting with the VR medium and content, as evidenced by their engagement and focus on specific elements within the experiences.

4.1.2. Challenges in Competence and Relatedness

However, they struggled with feelings of incompetence and relatedness, particularly when the VR stories lacked background information that participants felt they needed and hindered their understanding and connection. This was particularly true when participants did not have prior experience or knowledge of the IDEA topics. For example, participant FF noted how in *My Home, Shatila*, "It was very early on, her talking about how she wanted to be a lawyer in the future. I definitely want to, you know, get to know that element more." Moreover, Participant E, a 25-year-old, who recounts her experience with *Notes on Blindness*, explained, "I think it didn't, you didn't get a whole lot of personal information about him or like what was difficult about that experience."

My Home, Shatila, meanwhile, elicited the most discussion about the background story and context. Participants mentioned they did not know enough about conflicts in Syria to understand what led Fadia and her family to live in a refugee camp. Moreover, the lack of competence and relatedness could be due to participants' desire for interactivity during the 360° VR experiences. As 21-year-old participant Z described, *Coping with Alzheimer's* "felt more like a video I was watching rather than being physically there." As these were 360° VR videos, participants did not make decisions during their experiences that extended beyond where they decided to look.

The experiences left some participants feeling like observers rather than active participants, diminishing their sense of relatedness and immersion. Participants said they felt like they were the third wheel and an observer of the subject's situations, which stunted their ability to engage in perspective-taking. For instance, 19-year-old participant M described his thoughts about *Coping with Alzheimer's*, "The third wheel. That's what I felt like." Similarly, 21-year-old participant Z noted, "This felt more like a video I was watching rather than being physically there."

Specifically, the lack of extensive background information and interactivity in the VR experiences contributed to these perceptions, leaving some participants with a sense of detachment and discomfort during intimate moments depicted in the VR content. Thus, they felt they did not belong or feel a sense of relatedness during these experiences. This was primarily reported for *My Home, Shatila* and *Coping with Alzheimer's*.

4.1.3. RQ2: Immersive Empathy

The influence of prior IDEA experiences on perspective-taking (cognitive empathy) is multifaceted. Participants with no prior experience with the IDEA topics found that the immersive nature of the VR content forced them into a more empathetic engagement and gained perspective by placing them in scenarios that were markedly different from their daily lives:

> Being in that scenario really forces you to like feel....Like for the refugees, like, this is how they're living. Like you can't really refute the fact because you're standing in their home...[which], like, sort of like forces you to, like, feel, like, some amount of empathy. Just because you are there. (J, 23-year-old, describing *My Home, Shatila*)

Similarly, a lack of competence and autonomy, or a lack of control and the skills to change the environment, was also attributable to participants gaining an understanding of the VR content's subject's situations. For instance, in the case of *Notes on Blindness*, participants reported feeling a sense of helplessness when the visuals and audio cut out, as they had to rely solely on their hearing, just as John, the VR content's subject, had to when his sight disappeared:

> [When it] cuts out like at the end…the idea that like the world doesn't exist….And then all of a sudden there's a point where I was thinking about, like, what if you lost your hearing, too? And like how devastating that would be. (A, 42-year-old, describing *Notes on Blindness*)

Furthermore, participants reported experiencing perspective-taking and connecting with the subjects in the 360° videos on a human level even if they lacked a full understanding of the subject's circumstances:

> I don't really know um like the geopolitical difference between Syria and Lebanon. So, like I can't say like, "Oh, this is like a stance on this country, stance on that country"….And like the significance, you know, it doesn't really matter, because at the end of the day…they're just trying to go through their day as much as I'm trying to go through mine…that's how they go about their day and they're just people. (II, 21-year-old, expressing his connection with Fadia in *My Home, Shatila*)

4.1.3.1. Projecting Instead of Perspective-Taking

However, perspective-taking differed depending on whether participants had previous experience (personal or close other) with IDEA-related topics. Specifically, of the participants, few verbally expressed having first-hand experience with the IDEA situations. Instead, participants mentioned either working closely with or having a close other (e.g., spouse) who experienced a similar situation to those that were presented in the 360° videos such as poor living conditions or experiencing blindness through simulated classroom exercises. Their knowledge of the situations came from witnessing or hearing reports of a close other's experiences. For example, as 28-year-old participant GG reflected on all three VR experiences, "I'd worked with blind people before and that has stuck with me, too, through these many years. And today again, I got to experience…similar stuff. And definitely, it has got, that feeling has gotten stronger." Furthermore, the IDEA VR experiences activated memories and reminded participants of those close to them who had experienced or are experiencing similar situations.

The IDEA-themed VR experiences evoked participants to project their close others' (i.e., a significant person in their lives) social plight and struggles into the VR content. This projection sometimes limited their ability to adopt the perspective of the VR subjects directly, focusing instead on how the content resonated with their own or their close others' experiences. For instance, as 51-year-old participant N discussed *My Home, Shatila*, she explained "I had a friend in school. She was from Lebanon, so it made me think, is that what, how she grew up?"

Often, participants related specific hardships depicted in these experiences with similar hardships of a close other. Participants spoke of their grandparents or family members' plight. For example, 35-year-old G explained, "The lady said, 'I wish I am able to remember what I have forgotten.' I think my grandmother was a, she just listened to mostly, but she was recognized with this Alzheimer's" while discussing *Coping with Alzheimer's*. Similarly, 23-year-old W described her father's experiences after engaging with *My Home, Shatila*:

> My dad's from Iran. It's like, it's kind of a similar environment…stuff is not as like stable as it is here, like a water source or even like electricity and things that we take for granted. That just kind of takes me back to reality. Like, that's not everywhere in this world.

Additionally, participants who expressed projections of a close other's situations in the VR content also expressed imagining themselves as their close other's caretakers or supporters. Participants focused more on how certain circumstances depicted within the narratives would impact their lives if they were faced with the same challenges: "Because I think, in my mind, [my husband] is the one who's going to get sick…according to genetics….So, I see ourselves living like that, like he gets sick, and I take care of him" (AA, 30-year-old, after engaging with *Coping with Alzheimer's*).

Similarly, 23-year-old participant J, projected his grandparents in *Coping with Alzheimer's*: "My grandparents now are in assisted living and…they're having memory issues….It's like a, like a short documentary of like…my experience, I guess. But like, from the perspective of them."

The trend of projecting instead of perspective-taking could be due to understanding what it is like to be a caretaker or be a supportive figure in their lives because they are close to others who are living with Alzheimer's, blindness, or who have lived in a refugee camp. Correspondingly, *Coping with Alzheimer's* evoked perspective-taking for Aline's husband, Walt, instead of Aline, who was living with Alzheimer's. When imagining being in the experience, participants often imagined being in his shoes rather than hers: "More towards of the caretaker. I do feel like sympathy for [the] person with Alzheimer. But at the same time…her husband, like….It's like, it's a difficult job. I mean, it's a caring labor…so I feel more sympathized over the caretaker" (DD, 23-year-old).

Interestingly, when participants projected close others into the VR videos, it reminded and reinforced how they thought and felt toward close others but did not extend perspective-taking toward the subjects of the VR narratives. Instead, these narratives evoked considerations for matters of self-interest.

Repeatedly, participants admittedly felt for subjects in the situations depicted in the VR narratives but said little about the subjects depicted within the narratives themselves. Often, the conversations during interviews gravitated toward topics that related back to the individual's concerns for a close other or themselves: "I'm in my 30s, and I'm preparing myself to have, you know, the safety and security for my parents…because I've already seen my grandmother having Alzheimer's, I'm like, 'Oh ok, my mom' " (G, 35-year-old, explaining why *Coping with Alzheimer's* made her feel the most deeply).

4.1.3.2. Gaining Perspective and a Call to Action

Despite these variations, both groups of participants—those with and without prior experience—reported gaining valuable perspective from the VR experiences. For example, as 24-year-old participant HH noted how *Notes on Blindness*, "I got to learn about the perspective of a blind person, how he sees the world through his inner feelings."

Prosocial attitudes and behaviors were reported, with participants mentioning their intentions to be more considerate, understanding, and respectful to others. While discussing *Coping with Alzheimer's*, for example, 21-year-old participant Z noted, "It made me more aware of accessibility, which is something I'd like to be more mindful of." During a discussion about empathy, 21-year-old participant Y similarly commented, "It makes me think, 'What can I do to make the situation better?' While I may not be able to relate directly, I can understand the daily challenges they must be facing." Similarly, participant B, 22-year-old, stated:

> If anything, you just made me think about others, and I think it reminded me to remember to think about others in my daily life. Like, not just myself. And to just be, I guess, more conscious of other people and what they might be going through.

4.2. Quantitative Findings

4.2.1. No Significant Link Between Experience and Cognitive Load

To explore the extent of the relationship between prior IDEA experiences and cognitive effort, several linear regression coefficient test analyses were conducted to test the relationship between prior IDEA experiences and cognitive effort score (RQ3). In each scenario, there was no significant relationship found between prior IDEA experiences (personal or close other) and cognitive effort (*Coping with Alzheimer's*, $F\ (1{,}33) = 0.46$, $R^2 = 0.01$, $p = 0.50$; *Notes on Blindness*, $F\ (1{,}33) = 0.28$, $R^2 = 0.01$, $p = 0.60$; *My Home, Shatila*, $F\ (1{,}33) = 0.57$, $R^2 = 0.02$, $p = 0.46$).

Therefore, IDEA 360° VR videos do not put individuals who have prior experience with living in a refugee camp, blindness, or Alzheimer's disease in an overwhelmed cognitive state. In other words, participants who reported having prior experience do not experience greater cognitive effort spikes than those who do not have previous experience with IDEA. Given that cognitive effort spikes represent increased cognitive exertion, significant findings would suggest that greater prior experience correlates with higher cognitive effort exertion. However, this outcome would not be ideal, as cognitive effort indicates mental exertion or inefficient allocation of cognitive resources, potentially leading to disengagement with the content. Findings also indicate other factors might play a more significant role in determining cognitive effort levels.

4.2.2. Cognitive Effort and Prosocial Behavior

To address whether there is a relationship between cognitive effort and prosocial attitudes and behaviors (RQ4), simple linear regression analyses were performed. In each scenario, there was no statistically significant relationship found between cognitive effort and prosocial attitudes and behaviors (*Coping with Alzheimer's*, $F\ (1{,}33) = 0.37$, $R^2 = 0.01$, $p = 0.55$; *Notes on Blindness*, $F\ (1{,}33) = 0.00$, $R^2 = 0.00$, $p = 0.97$; *My Home, Shatila*, $F\ (1{,}33) = 0.41$, $R^2 = 0.01$, $p = 0.53$). We used Cook's distance sensitivity analysis to investigate whether outliers affected our findings on the relationship between cognitive effort and prosocial attitudes. While we found no significant results for *Coping with Alzheimer's* and *Notes on Blindness*, excluding outliers, *My Home, Shatila* ($n = 27$) revealed a significant effect of cognitive effort on prosocial behaviors ($p < 0.01$). This suggests that outliers affected the initial results. This relationship may be significant in certain VR experiences.

5. Limitations and Future Directions

A small sample size constrained our study, and our findings may not be generalizable. Notably, the majority of our sample identified as Democrats (40%) compared to any other political party and could have different ideologies on the IDEA topics, which could have impacted cognitive effort. Future studies should include a more representative sample for generalizability. Additionally, prosocial attitudes were assessed only once after VR engagement, making it challenging to determine their pre-existing levels.

Moreover, participants also mentioned the brevity and the lack of interactivity of VR experiences. Future studies could explore using longer stories that offer more background information, narrative depth, and interactive options. Additionally, this study did not assess the specific types of cognitive loads. Therefore, future research should categorize cognitive load (e.g., germane, intrinsic, and extraneous cognitive load; see Sweller, 2010) to better understand how each type of cognitive effort contributes to the development of cognitive empathy in immersive environments. Furthermore, future studies should investigate how perspective-taking mediates the impact of VR experiences on affective responses toward people who demographically differ from themselves.

As researchers continue to explore the importance of SDT and cognitive effort impacting one's ability to engage with perspective-taking in IDEA VR contexts, it is also essential to consider users' prior experience with such topics. Although our findings suggest prior experience does not correlate with nor have a statistically significant effect on cognitive effort, VR creators should still consider consumers' prior experience when designing IDEA-related VR content, especially if they want consumers to adopt prosocial attitudes and behaviors.

6. Conclusion

Our mixed-methods study revealed SDT (or the lack thereof) and perspective-taking emerge through discussions of prior experiences (close, other, and personal) after engaging with three 360° IDEA-centered VR videos. We find that of the three components of SDT, participants discussed autonomy as something that enhanced a participant's engagement with the 360° videos because they felt like they had a sense of agency over where they could look (RQ1). Contrastingly, they felt a lack of relatedness, describing feelings of being unwanted or needed. In addition, participants reported an absence of competence when the VR content lacked a detailed background story or when participants did not have prior knowledge of the VR subject's situation.

Moreover, our findings suggest that prior experience influences how people engage with perspective-taking (RQ2). Through interviews, we found that most participants themselves did not experience the observed IDEA topics, but a close other did. Further, findings indicate that close others' prior experience may lead to projecting or imagining a close other in the VR experience rather than themselves.

Additionally, we did not find a statistically significant relationship between prior experience and cognitive effort (RQ3). However, this is an encouraging finding in that those who have personal or close experience of struggles with Alzheimer's, blindness, or living in a refugee camp did not exert more cognitive effort than those with less or no previous experience with the observed IDEA topics.

Lastly, we did not find a statistically significant relationship between one's prior experience and prosocial attitudes and behaviors (RQ4). This is inconsistent with Depow et al. (2022) findings that show people are more likely to engage with prosocial attitudes and behaviors if the cause closely relates to them. This inconsistency may be due to participants' introspection and appreciation of what they have rather than expressing a willingness to enact societal change. However, it is worth noting that some participants expressed that they would like to be more considerate of others.

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Conflict of Interests

The authors declare no conflicts of interests.

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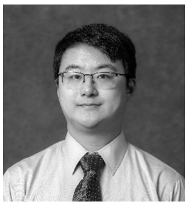

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Harnessing 360-Degree Video to Prompt Users to Think Along With Pro-Environmental Campaign Messages

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Abstract

Three-hundred-and-sixty-degree videos visualized through virtual reality (VR) technologies are recognized as an effective tool for fostering positive attitudes towards environmental stewardship by immersing users in persuasive storytelling narratives. However, a lack of an overarching framework hinders the understanding of its role in promoting prosocial environmental behaviors, particularly its effects on information processing and behavioral intentions. Notably, recent studies have suggested that feeling transported into a VR environment (i.e., presence) could positively bias message evaluation and the way people process information by activating heuristics connected to immersive experiences (i.e., the bias hypothesis of the heuristic-systematic model). Drawing on this proposition, this study conducted a between-subject design experiment ($N = 60$), comparing a 360-degree pro-environmental campaign video in VR with that in a two-dimensional format. Results from partial least squares structural equation modeling indicated that a 360-degree video in VR induced a higher sense of presence, yet heuristic evaluation of message credibility decreased when a sense of presence was low. Moreover, message credibility was found to be positively associated with the valence (consistency) of message-relevant thoughts, but moderate evaluation of message credibility buffered the generation of consistent message-relevant thoughts. Finally, the valence (consistency) of message-relevant thoughts had a curvilinear relationship with the intention to engage in pro-environmental behaviors, albeit with a small effect size. Results suggest the complexity in influencing behavioral intentions via 360-degree videos in VR. Nonetheless, the findings support the proposition that the immersive affordance of immersive storytelling content could prompt users to align with campaign messages by activating a positive heuristic bias.

Keywords

cognitive elaboration; immersive storytelling; presence; pro-environmental campaign; virtual reality

1. Introduction

Advances in immersive technologies, such as 360-degree videos (i.e., omnidirectional videos that allow the panoramic view of scenery; Cinnamon & Jahiu, 2023) and virtual reality (VR), have sparked a wave of interest from researchers in exploring their potential as tools for immersive storytelling. Notably, 360-degree video content has garnered significant interest from researchers for its capacity to immerse users in compelling narratives and induce the sense of being part of realistic scenarios without incurring high costs compared to VR content (Evens et al., 2023).

Although the efficacy of employing 360-degree videos for immersive storytelling has been actively examined by previous researchers across various domains such as advertising (Feng, 2018), historical education (Pehlivanides et al., 2020), and safety training (Z. Ma, 2022), a considerable amount of research has been focused on testing its effectiveness in the domain of environmental communication (e.g., Oh et al., 2020; Oh, Jin, et al., 2021). Most of the previous studies examining the role of 360-degree videos in environmental communication seem to agree that storytelling environmental issues through a 360-degree video could significantly promote prosocial environmental behaviors compared to traditional videos (i.e., non-panoramic videos). Furthermore, numerous studies suggest that the effectiveness of 360-degree videos in storytelling could be amplified when persuasive narratives are visualized through a VR head-mounted display (HMD; Amrhein & Balaban, 2024; Breves & Heber, 2020; Cinnamon & Jahiu, 2023; Fraustino et al., 2018). Nonetheless, we are still left with a few gaps in knowledge that hinder a clear understanding of the cognitive mechanism underlying the role of 360-degree videos in immersive storytelling for promoting prosocial environmental behaviors.

First, we aim to test the potential of 360-degree videos in immersive storytelling for promoting pro-environmental behaviors, with a particular focus on defining "immersiveness" as a key affordance of 360-degree videos viewed through a VR HMD. This focus is informed by previous studies that often identify "interactivity" as the primary affordance of 360-degree videos compared to traditional video content (e.g., Oh et al., 2020; Oh, Jin, et al., 2021), or overlook the potential for interactivity in 2D content filmed with 360-degree cameras (e.g., Breves & Heber, 2020). The increase in immersiveness, encompassing both vividness and interactivity (Slater & Wilbur, 1997; Steuer, 1992), is known to induce a sense of spatial presence, making users feel as if they are situated within the mediated environment (Wirth et al., 2007). By defining immersiveness through the combined effects of enhanced vividness and interactivity afforded by 360-degree videos viewed through VR HMDs, we aim to gain a clearer understanding of how immersive technologies can be leveraged to effectively design immersive storytelling content.

Second, given that there is a lack of an overarching framework that provides a clear understanding of the underlying mechanism of the efficacy of 360-degree videos in immersive storytelling, the current study attempts to provide a theoretical explanation of how 360-degree videos in combination with a VR HMD used for storytelling environmental issues could influence the behavioral intentions of users. Specifically, the current study aims to test the propositions of the four-step model of persuasion by spatial presence (Breves, 2023), in which a sense of presence induced by the immersive affordance of a technology is predicted to positively bias the persuasive effects of immersive technologies by positively biasing the heuristic evaluation of messages and the way users process message-relevant information (i.e., the bias hypothesis of the heuristic-systematic model; Chaiken & Maheswaran, 1994). The validation of the framework suggested by

Breves (2023) may provide insights into a better understanding of the persuasion process underlying the use of recent immersive technologies for storytelling.

Lastly, using a partial least squares structural equation modeling (PLS-SEM) technique, we aim to provide a nuanced understanding of the possible nonlinear relationship among the constructs included under the four-step model of persuasion by spatial presence (Breves, 2023). The explication of the nonlinear relationship among perceptual variables such as presence and credibility, and cognitive and behavioral variables such as information processing and behavioral intentions may significantly advance existing scholarship by allowing a clearer understanding of the contextual effects of immersive technologies and their relevant variables.

2. Literature Review

2.1. Three-Hundred-and-Sixty-Degree Videos, Immersive Storytelling, and Environmental Communication

According to Cinnamon and Jahiu (2023), 360-degree videos (i.e., omnidirectional or spherical videos that allow the panoramic view of scenery) offer unique affordances and functionalities compared to traditional video formats, whereby users can dynamically explore scenes from various directions and angles through zooming and panning functions instead of having passive viewing experiences. Three-hundred-and-sixty-degree videos have advantages over VR content in that they could be relatively more easily and cheaply produced. While previous studies demonstrate and suggest that VR content can also effectively immerse users in persuasive narratives (e.g., Ahn et al., 2014; Behm-Morawitz & Shin, 2024; Meijers et al., 2023), the difficulty in developing VR content, with respect to costs and time required, has been considered one of the disadvantages of employing VR for immersive storytelling (Breves & Heber, 2020; Evens et al., 2023). Given this limitation, researchers and practitioners have been acknowledging 360-degree videos as an effective alternative to VR content.

Among the various domains in which the effectiveness of immersive storytelling has been tested, numerous studies have demonstrated a special interest in the use of 360-degree videos within the realm of environmental communication (Oh et al., 2020; Oh, Jin, et al., 2021). Supporting this, Cinnamon and Jahiu (2023), through a scoping review study, found that 42 out of 165 publications published between January 2011 and June 2022 examined the role of 360-degree videos in the context of environmental communication. As such, previous researchers have increasingly witnessed and showcased the benefits of using 360-degree videos in addressing sensitive issues (e.g., climate change, natural disasters; Fraustino et al., 2018; Oh et al., 2020). For example, Oh et al. (2020) found that 360-degree videos could enhance intentions to protect the environment compared to unidirectional videos in the context of environmental communication about climate change. Furthermore, multiple studies have demonstrated the positive impact of watching environmental issues through 360-degree videos on factors such as commitment to the environment (Breves & Heber, 2020), connection to nature (Sneed et al., 2021), interest in the environmental cause (Nelson et al., 2020), and intention to recommend the video (Amrhein & Balaban, 2024). In line with these findings, global nonprofit environmental organizations, such as the UN Environment Programme, have embraced this technology for immersive storytelling, recognizing its potential to engage audiences and raise awareness of pressing environmental issues by placing them at the center of the narrative (e.g., *Virtual Reality/360 Video: Meet Your Carbon Footprint*).

2.2. Immersiveness

Although relatively more costly than visualizing 360-degree content on-screen (i.e., a computer screen), previous studies demonstrate that the effectiveness of 360-degree videos in storytelling could be amplified when viewed through VR HMDs (Amrhein & Balaban, 2024; Breves & Heber, 2020; Cinnamon & Jahiu, 2023; Fraustino et al., 2018). The structural affordance of 360-degree content, which involves immersion through a panoramic view of scenery, suggests that its potential could be maximized when aligned with the structural affordance of VR HMDs. This alignment provides a greater degree of freedom in sensory (vividness) and motor (interactivity) engagement with immersive stimuli (Biocca, 1997), both of which are known to enhance the level of immersion.

In line with this idea, previous studies demonstrate that both the "vividness" and "interactivity" of immersive technology are important factors contributing to the level of immersion (Slater & Wilbur, 1997; Steuer, 1992). However, many studies investigating the impact of 360-degree videos have often operationalized "interactivity" as the primary feature of the technology, primarily comparing it with the static and non-interactive aspects of traditional video content (Oh et al., 2020; Oh, Jin, et al., 2021). Yet, 360-degree video viewed through VR HMDs also enhances the vividness of the experience by offering a greater degree of realism (i.e., sensory depth; Lombard & Ditton, 1997) through natural sensory engagement with stimuli, compared to 360-degree content viewed on 2D screens.

In this regard, defining interactivity as the primary structural affordance of 360-degree videos may not be sufficient for fully understanding the comparative effects of 360-degree videos viewed through VR HMDs versus 2D screens. VR HMDs enable users to engage more naturally with stimuli within the mediated environment, thereby enhancing the vividness of the experience. Additionally, while recent 360-degree videos viewed on computer screens also allow for some level of interaction (e.g., switching perspectives by dragging a mouse), this has often been overlooked by previous scholars (e.g., Behm-Morawitz & Shin, 2024; Breves & Heber, 2020; Meijers et al., 2023). Given this, it is important to clarify how interactivity in immersive storytelling using 360-degree videos can be further enhanced through the use of VR HMDs.

Technically, 360-degree videos viewed through VR HMDs can induce a stronger sense of vividness, as they provide a greater level of realism in sensory experiences (i.e., sensory depth; Lombard & Ditton, 1997) compared to 360-degree videos viewed on 2D computer screens. This enhanced vividness is facilitated by the panoramic view of scenery and higher screen resolution, which simulates the bodily visual experiences we have in physical environments. Furthermore, 360-degree videos viewed through VR HMDs should afford a higher level of interactivity compared to those viewed on 2D computer screens, as they allow for more natural interaction with the mediated environment through head rotation and controllers. Although 360-degree videos on 2D computer screens provide some level of interaction through mouse dragging, the interactivity provided by VR HMDs is likely to be more robust, due to factors such as speed (i.e., immediacy of feedback), range (i.e., degrees of freedom), and mapping (i.e., naturalness) that determine the strength of interactivity (Steuer, 1992). Specifically, motor engagement with mediated stimuli through VR HMDs should be more immediate and natural, offering a greater degree of freedom and a larger number of possible actions compared to engagement with the same stimuli through 2D computer screens. The stronger sense of vividness and interactivity afforded by 360-degree videos viewed via VR HMDs should, therefore, amplify user immersion compared to 360-degree videos viewed on 2D computer screens, regardless of the level of interaction afforded by mouse movement on the latter.

2.3. (Spatial) Presence

A considerable number of previous studies have predominantly suggested that at the heart of the enhanced immersiveness through 360-degree videos in HMDs lies the concept of presence (i.e., a sense of being located in the midst of the mediated environment; Wirth et al., 2007). As seen in previous studies (e.g., Amrhein & Balaban, 2024; Breves & Heber, 2020), the sense of presence, induced by the immersiveness of mediated experiences, provides useful guidance in understanding the underlying mechanism of the efficacy of 360-degree videos in immersive storytelling.

To describe the feeling of "being there" in a mediated environment, the concept of presence has been developed (Sundar, 2008). Presence is a construct that has garnered significant attention from researchers aiming to elucidate the cognitive mechanisms underlying the use of immersive media (e.g., Lee, 2004). In the context of using 360-degree videos for immersive storytelling, the definition provided by Wirth et al. (2007) offers an intuitive understanding of the perceptual mechanisms underlying the sense of presence, specifically as a sense of being situated in the midst of the mediated environment.

As explained earlier, immersion, which refers to the extent to which the user experiences the mediated environment as vivid and interactive (Steuer, 1992), plays a crucial role in determining the sense of (spatial) presence (Wirth et al., 2007). For instance, if a mediated experience is perceived as realistic, with high sensory depth (e.g., a large field of view and high screen resolution), and provides immediate and natural feedback to the user's actions (e.g., an immediate change in perspective when looking in another direction), users are likely to evaluate the mediated environment as immersive (Biocca, 1997; Steuer, 1992). When the mediated experience is immersive, users are likely to feel as if they are in the midst of the environment, as demonstrated by previous studies (Amrhein & Balaban, 2024; Breves & Heber, 2020). Consistent with this notion, numerous studies examining the role of 360-degree videos in enhancing (spatial) presence have consistently shown that the vivid and interactive nature of 360-degree videos can induce a greater sense of presence compared to 2D video content (e.g., Fraustino et al., 2018; Oh et al., 2020). However, only a limited number of studies have tested the efficacy of using VR HMDs for viewing 360-degree videos compared to using 2D computer screens with interactive features in the context of environmental communication (e.g., Amrhein & Balaban, 2024). To assess the efficacy of using VR HMDs for viewing 360-degree videos compared to 2D computer screens with interactive features (i.e., perspective switching via keyboard and mouse dragging), we first propose the following hypothesis:

> H1: Three-hundred-and-sixty-degree videos visualized through VR HMDs will induce a greater sense of presence than 2D video content.

2.4. The Four-Step Model of Persuasion by Spatial Presence

Although presence has often been employed to guide previous studies, it remains unclear how presence may influence behavioral intentions in the context of immersive storytelling. This ambiguity arises from the fact that various studies often utilize different theories and constructs to predict engagement with environmental issues or behavioral intentions. Consequently, this diversity has led to mixed explanations regarding the interpretation of the role of presence induced by the use of 360-degree videos in engaging with environmental issues (e.g., Oh, Jin, et al., 2021).

Specifically, in the study by Oh, Jin, et al. (2021), presence was rather found to have a negative impact on engagement with environmental issues, despite the general understanding that presence increases engagement. This unexpected result suggests a need for further investigation and reveals a potential gap in our current understanding of how presence operates in the context of immersive storytelling, particularly concerning environmental issues. Employing a solid framework that integrates the role of presence and various findings in the domain of immersive storytelling would enable researchers to systematically examine the role of presence induced by the use of 360-degree videos in engaging with environmental issues.

Notably, recent studies (e.g., Breves, 2021) have suggested that feeling transported into a VR environment (i.e., presence) could positively bias message evaluation and the way people process information by activating heuristics connected to immersive experiences (i.e., the bias hypothesis of the heuristic-systematic model; Chaiken & Maheswaran, 1994). This implies that exploring how presence influences information processing in immersive storytelling contexts could provide valuable insights into the mechanisms driving behavioral intentions.

The four-step model of persuasion by spatial presence developed by Breves (2023) further details how 360-degree videos, when combined with a VR HMD for storytelling environmental issues, could influence the behavioral intentions of users. The model proposes that a sense of presence induced by the immersive affordance of technology positively biases the persuasive effects of immersive technologies by influencing the heuristic evaluation of messages and the valence (and the consistency) of processed information (i.e., as in the bias hypothesis of the heuristic-systematic model; Chaiken & Maheswaran, 1994). This theoretical framework offers a structured approach to understanding the persuasive mechanisms behind the use of immersive technologies, thereby explaining their potential impact on behavioral intentions.

The heuristic-systematic model (Chaiken, 1980) suggests that users may often rely on cognitive shortcuts, passively consuming messages without thorough cognitive processing. This model posits two modes of information processing, heuristic and systematic, which can dynamically interact and influence each other. The bias hypothesis of the heuristic-systematic model (Chaiken & Maheswaran, 1994) illustrates how these modes can affect each other, suggesting that initial evaluations of persuasive content are guided by certain heuristics, potentially shaping subsequent systematic processing. For example, viewers' perception of the credibility of a 360-degree video may impact their processing of its message.

Building on the propositions of the bias hypothesis of the heuristic-systematic model (Chaiken & Maheswaran, 1994), Breves (2023) further suggests that the sense of presence induced by immersive technologies may activate a positive heuristic. This positive heuristic, such as "if something looks real, it must be good" (Sundar, 2008), could lead users to appreciate the mediated experience and form positive evaluations of the message conveyed, including perceptions of credibility and enjoyment. Supporting this notion, Bracken (2005) demonstrated that the sense of spatial presence can serve as a heuristic for assessing the credibility of the message source. Additionally, Breves (2021) provided direct evidence that the sense of spatial presence can positively influence the evaluation of message source credibility. Although a different outcome variable was tested, a recent study by Behm-Morawitz and Shin (2024) also found that presence is associated with positive perceptions of pro-environmental video content.

However, the study by Greussing (2020), which compared the effects of 360-degree photography with video, still photos, and plain text, found a detrimental effect of adding the 360-degree feature on message credibility. We suspect that this contradictory result stems from the implementation of 360-degree technology in photography, which may have afforded an unnatural interaction with the stimuli, leading to a diminished sense of presence. Since photography is inherently static, adding a dynamic and interactive feature to it may have backfired, negatively impacting the perceived credibility of the message source. Thus, we argue that the alignment between the affordances of video and 360-degree technology (i.e., both dynamic) will yield different outcomes, as predicted by the theoretical propositions of Breves (2023) and the relevant findings (Behm-Morawitz & Shin, 2024; Bracken, 2005; Breves, 2021). Specifically, we posit that:

> H2: The sense of presence will be positively associated with the evaluation of message credibility.

According to the four-step model of persuasion, the subsequent valence of cognitive processing is expected to be positively biased, aligning with the immersive experience when there is a positive evaluation of message credibility influenced by the sense of presence. In this model, cognitive elaboration of message content goes beyond the quantity of thoughts generated, encompassing their valence—specifically, whether the thoughts are consistent (positive) or inconsistent (negative) with the message delivered by the immersive media content. Given the likelihood of viewers positively evaluating the credibility of environmental issue content conveyed through 360-degree videos due to their immersive nature, this study suggests that the positive heuristic evaluation may lead to a predominance of message-relevant thoughts consistent with the message conveyed within the 360-degree video, thus supporting the bias hypothesis.

Albeit limited, a few studies provide empirical evidence that positive evaluations of media experiences can lead to the generation of fewer negative message-relevant thoughts (Breves, 2021; C. Ma et al., 2020). This suggests that an increase in message credibility may encourage people to generate thoughts that are more aligned with the central messages. Based on these theoretical considerations and relevant findings, the following hypothesis is proposed:

> H3: The evaluation of message credibility will be positively associated with the valence (consistency) of message-relevant thoughts generated via cognitive elaboration.

Finally, the four-step model of persuasion proposes that the valence (i.e., consistency) of cognitive elaboration, positively biased by heuristic evaluation of messages, can influence persuasion (e.g., behavioral intention) in the same direction as the experienced bias. However, despite this theoretical framework, previous studies have often failed to find a significant effect of immersive technologies on behavioral intention (e.g., Plechatá et al., 2022). We suspect that the reason for these insignificant findings may lie in the curvilinear nature of the relationship between cognitive processing of information and behavioral intentions. In other words, there could be a threshold for the valence (consistency) of cognitive elaboration above which people may start forming intentions to engage in pro-environmental behaviors. Nonetheless, the study of Hovick et al. (2011) suggests that information processing may positively influence behavioral intentions. In addition, Behm-Morawitz and Shin (2024) found the indirect effects of VR immersive video on behavioral intentions in the context of pro-environmental video content. Integrating these findings, the current study posits that the valence (consistency) of cognitive elaboration may have a positive, yet curvilinear, relationship with the behavioral intention to engage in pro-environmental behaviors:

> H4: The valence (consistency) of message-relevant thoughts generated via cognitive elaboration will have a positive, yet curvilinear, relationship with behavioral intention to engage in pro-environmental

behaviors, with behavioral intention expected to start increasing when the valence of message-relevant thoughts becomes positive.

3. Methods

3.1. Experimental Design

A laboratory experiment with a two-factor (mode of presentation: monoscopic 2D vs. stereoscopic VR) between-subjects design was conducted, having presence as an independent variable, message credibility and cognitive elaboration as serial mediators, and intention to engage in pro-environmental behaviors as a dependent variable. Figure 1 presents a holistic view of the proposed research model.

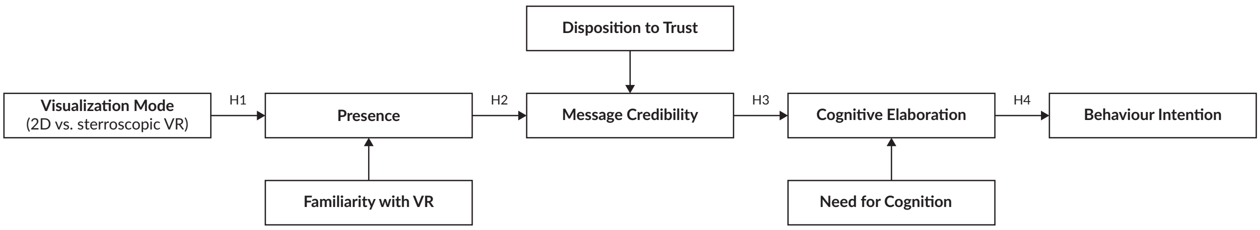

Figure 1. Proposed research model.

3.2. Participants

A total of 60 participants were recruited through a research participant recruitment system and personal invitations at a public university in Western Europe. Due to the limitations of existing power analysis methods in estimating the sample size for a mediation model with more than two serial mediators, the sample size was determined based on the research design employed by Breves and Heber (2020). Using a two-condition between-subjects design experiment (360-degree video vs. monoscopic 2D) with a sample size of 56, Breves and Heber (2019) found a large effect size regarding the effects of the mode of presentation (360-degree video vs. monoscopic 2D) on spatial presence ($\eta^2 = .51$) and commitment to the environment ($\eta^2 = .16$). The descriptive statistics provided for the dependent variables used in the study were employed to estimate the sample size. Results from an a priori power analysis using G*Power version 3.1.9.7 (Faul et al., 2007) indicated that the required sample size for our study could range from a minimum of 12 to a maximum of 46, with the power and alpha error probability set at 80% and .05, respectively.

The average age of participants was 28.85 years old ($SD = 12.72$), ranging from 18 to 60. Among the participants, 51.67% ($n = 31$) were female, and 48.33% ($n = 29$) were male. To mitigate potential gender effects, participants were evenly distributed across conditions. Specifically, 15 females and 15 males were assigned to the stereoscopic VR condition, while 16 females and 14 males were assigned to the 2D condition.

3.3. Stimuli

A video that depicted the impact of climate change on the island of Palau, titled *Coral Compass: Fighting Climate Change in Palau* (Virtual Human Interaction Lab, 2019), was used as an experimental stimulus for this study.

The video provided both 2D and stereoscopic VR (360-degree) experiences. While the 2D condition allowed users to adjust the viewpoint with the keyboard and mouse, the VR condition enabled the viewers' head movements with an HMD to experience the content. The HTC Vive was used in the VR condition.

The experience began with an introduction to the coral reefs of Palau, followed by a depiction of the coral reefs that had been damaged by the tourism industry. It then transitioned to Palauan senators and marine ecologists discussing restoration efforts and the use of taro farms as a solution to prevent sediment from harming the reefs. The strategic placement of taro farms was initiated in order to prevent sediments from reaching the oceans, as sediments can be disseminated by rainfall and have proven to be harmful to the coral reefs. As a result, taro farms are shown to effectively block up to 90% of these sediments, playing a crucial role in coral protection. The experience concluded with the presentation of a successfully restored coral reef, illustrating that the role of humanity is critical for the recovery and conservation of nature. The example scenes of the stimuli are presented in an OSF folder (https://osf.io/2yzrk/?view_only=aa6ef8cd78d84d75a1851246526d4f9c).

3.4. Measures

Presence was measured using five 5-point Likert scale items adapted from Makransky et al. (2017). Participants were asked how much they perceived the sense of presence while experiencing the experiment stimuli (e.g., "The environment seemed real to me").

Message credibility was evaluated using four 5-point Likert scale items adopted from Oh, Khoo, et al. (2021). Participants were asked to indicate how they perceived the message of the campaign (e.g., "I believe the content was believable," "I believe the content was informative").

Cognitive elaboration (the valence of message-relevant thoughts) was assessed using a three-minute thought-listing technique (Cacioppo & Petty, 1981). After exposure to the experimental stimuli, participants listed their thoughts about the pro-environmental content they recalled for three minutes. Once the listing process was complete, two coders independently assessed whether the listed thoughts were relevant or irrelevant to the content's message. Only thoughts directly relevant to the message were counted as message-relevant, while those related to peripheral aspects, such as technical and aesthetic details, were excluded.

Next, the number of message-relevant thoughts (i.e., cognitive elaboration) was tallied and coded based on thought valence: positive or negative. Following Step 3 of the four-step model of persuasion (Breves, 2023), thoughts consistent with the central messages of the content were coded as positive, while thoughts inconsistent with the central messages were coded as negative. For example, thoughts that supported the content's message about climate change and encouraged pro-environmental behaviors were coded as positive elaborations. Conversely, thoughts that contradicted the message, such as questioning the effectiveness of the campaign, were coded as negative elaborations.

Two independent coders used a coding scheme that included a brief description of valence and examples from the first 20 coded sentences. The inter-coder reliability, measured using Krippendorff's alpha (Krippendorff, 2018), was high, exceeding .80 for both positive and negative message-relevant thoughts (positive elaboration: α = .925; negative elaboration: α = .997), indicating strong agreement between coders. To determine the amount and valence of cognitive elaboration, the number of negative (inconsistent) message-relevant thoughts was subtracted from the number of positive (consistent) message-relevant thoughts and then divided by the total number of message-relevant thoughts, following the method outlined by Breves (2021). This calculation yielded a valence score ranging from −1 to 1, where positive and negative values indicated the valence of message-relevant thoughts generated after experiencing either the 360-degree video or monoscopic 2D video. Examples of participants' cognitive elaboration and the corresponding coding results are presented in Table 1.

Intentions to engage in pro-environmental behaviors were measured by five 5-point Likert scale items adapted from Oh et al. (2020). Participants were asked to rate their intentions to engage in specific pro-environmental behaviors, including efforts to reduce environmentally harmful actions (e.g., "I will become active in supporting the government to pass stricter laws to stop climate change").

Additionally, this study measured three covariates. First, familiarity with VR was measured with a 5-point scale item ("How familiar are you with VR?"), ranging from *not familiar at all* (1) to *extremely familiar* (5; M = 2.30,

Table 1. Examples of participants' cognitive elaboration and corresponding coding results.

Cognitive elaboration	The number of message-relevant thoughts	
	Positive (consistent)	Negative (inconsistent)
There is a significant change in the environment.	1	0
It is a serious problem, and most people are unfamiliar with it and its causes. It's good to bring attention to it, but for me, this video wasn't particularly motivating. Additionally, the VR function using a mouse didn't play an additive role.	1	1
It is nice that you can see the ocean from left to right. My mind didn't stay on the voice because I got distracted.	0	0
I felt a bit like I was in the real world, and I was worried about what will happen to the world due to climate change.	1	0
It seemed to me that we, as people, are ruining the planet, and most of the time we don't even notice. I also went snorkeling at one point, and watching this video made me feel a bit guilty about that because it felt like I also contributed to damaging reefs and corals. It made me realize that we have a really beautiful planet, and we should take better care of it.	3	0
The ocean is a beautiful place that should be preserved, and it is a shame that it is currently not treated that way.	1	0
I had the same feelings as if I were watching a regular video. Since I was still looking at a flat screen, the VR effect didn't add much for me. I didn't feel immersed in an "alternate reality." While the video itself looked nice, the issues described felt distant and didn't emotionally engage me or motivate me to take any specific action.	0	1

Notes: The grammatical errors in the raw answers were corrected to enhance readability; the complete data regarding the coded answers are available at https://osf.io/2yzrk/?view_only=aa6ef8cd78d84d75a1851246526d4f9c.

SD = 1.03). This item was measured to control for the potential novelty effects that could confound the pure impact of the VR experience (Fussell et al., 2019).

Disposition to trust was measured by eight 7-point Likert scale items adopted from McKnight et al. (2002). Given that participants' pre-existing tendency to trust could influence their receptivity to the messages in the experimental stimuli (Gefen et al., 2003), disposition to trust was included as a covariate in the research model. Participants were asked to assess their propensity to trust others (e.g., "In general, most folks keep their promises").

Need for cognition was measured and controlled using ten 7-point Likert scale items adapted from Pacini and Epstein (1999). In our research model, need for cognition was included as a control variable to account for individual differences in cognitive information processing (Cacioppo & Petty, 1982) and its impact on persuasion (Petty & Cacioppo, 1986). Participants were asked to evaluate how much they are usually inclined to engage in effortful cognitive activities (e.g., "I try to avoid situations that require thinking in depth about something").

3.5. Procedure

Upon completing the informed consent process, participants were invited to a university laboratory in Western Europe and randomly assigned to either the 2D or stereoscopic VR experimental condition. In each session, only one participant at a time experienced the stimuli through either a 360-degree video or a monoscopic 2D video, depending on their assigned condition. After exposure to the stimuli, participants were instructed to complete a questionnaire about their experience, which included questions on latent variables (e.g., presence, message credibility), covariates, and demographic information. Upon finishing the survey, participants received 0.5 course credits in accordance with the university's internal guidelines. The duration of each experiment was approximately 30 minutes.

3.6. Data Analyses

Given the exploratory nature of the proposed hypotheses, this study employed PLS-SEM. PLS-SEM was chosen for its suitability in handling complex structural models with relatively small sample sizes (Goodhue et al., 2012). Additionally, previous studies have recommended PLS-SEM as an alternative to covariance-based structural equation modeling when addressing concerns about sample size adequacy (Hair et al., 2014, 2017). Furthermore, PLS-SEM was used to examine the curvilinear relationships among variables. WarpPLS 8.0 (Kock, 2022) was used as the analytical software for the analysis.

4. Results

4.1. Measurement Validity

Prior to the hypotheses testing, the validity of the measurement model was tested. The raw data were standardized before testing the measurement and structural models. Based on the guidelines of Kock (2022), this study examined whether (a) item loadings were equal to or greater than .50 and (b) the *p* values of item loadings were below .001. As a result, five items were removed due to having item loading below .50.

To confirm convergent validity, the average extracted variance was evaluated to ensure it exceeded .50. To ensure the discriminant validity, the Heterotrait–Monotrait ratio was assessed, with the requirement that it be below .90. Next, internal reliability of the measurement items was ensured by testing both composite reliability and that Cronbach's α exceeds .70 (Hair et al., 2014). Table 2 presents the results of the measurement validity, including item loading, average extracted variance, and internal reliabilities. Table 3 shows the Heterotrait–Monotrait ratio.

Table 2. Item loading, average extracted variance, and internal reliabilities of constructs.

Construct	Item	Loading	Average extracted variance	Composite reliability	Cronbach's α
Presence	P1	.730***	.742	.856	.786
	P2	.759***			
	P3	.515***			
	P4	.890***			
	P5	.764***			
Message credibility	MC1	.842***	.825	.865	.766
	MC3	.826***			
	MC4	.808***			
Behavior intention	BI1	.633***	.687	.816	.718
	BI2	.771***			
	BI3	.643***			
	BI4	.741***			
	BI5	.636***			
Disposition to trust	DT1	.704***	.682	.874	.835
	DT2	.668***			
	DT3	.676***			
	DT4	.725***			
	DT5	.644***			
	DT6	.710***			
	DT7	.612***			
	DT8	.706***			
Need for cognition	NFC1	.747***	.699	.850	.787
	NFC2	.789***			
	NFC3	.744***			
	NFC5	.612***			
	NFC9	.646***			
	NFC10	.636***			

Notes: P = presence; MC = message credibility; BI = behavior intention; DT = disposition to trust; NFC = need for cognition; *** $p < .001$.

Table 3. Heterotrait–Monotrait ratio.

Construct	Presence	Message credibility	Behavior intention	Disposition to trust	Need for cognition
Presence					
Message credibility	.388				
Behavior intention	.366	.282			
Disposition to trust	.389	.171	.349		
Need for cognition	.273	.320	.334	.303	

4.2. Hypotheses Testing

H1 posited that 360-degree video visualized through a VR HMD may induce a greater sense of presence than 2D video content. Results of PLS-SEM estimated a linear relationship between the variables and showed that the 360-degree video through a VR HMD ($M = 3.79$, $SD = .52$) induced a higher sense of presence than 2D video ($M = 3.03$, $SD = .79$), $\beta = -.46$, $p < .01$. Familiarity with VR, as a covariate, did not have a significant effect on the sense of presence ($\beta = -.16$, $p = .09$). In total, the mode of presentation, together with the covariate, explained 27% of the variance in the sense of presence ($R^2 = .27$). Therefore, H1 was supported.

H2 predicted that the sense of presence would be positively associated with the evaluation of message credibility. PLS-SEM estimated a non-linear relationship between the variables as the best solution (see Figure 2), indicating that the sense of presence is positively, yet curvilinearly, associated with the evaluation of message credibility ($\beta = .37$, $p < .001$). Disposition to trust did not have a significant impact on the evaluation of message credibility ($\beta = .05$, $p = .35$). The sense of presence, together with disposition to trust, explained 14% of the variance in the evaluation of message credibility ($R^2 = .14$). To confirm whether the curvilinear relationship was artificially influenced by outliers, we assessed whether the message credibility values around the low scores of presence in the scatter plot (Figure 3) were outliers in the 2D condition. According to the box plot analysis, none of these values were found to be outliers in the 2D condition, suggesting that the results are less likely to be affected by outliers. Therefore, H2 was supported.

H3 predicted that the evaluation of message credibility would be positively associated with the valence of thoughts generated via cognitive elaboration. Again, PLS-SEM estimated a non-linear relationship between the variables as the best solution (see Figure 4), demonstrating that the evaluation of message credibility

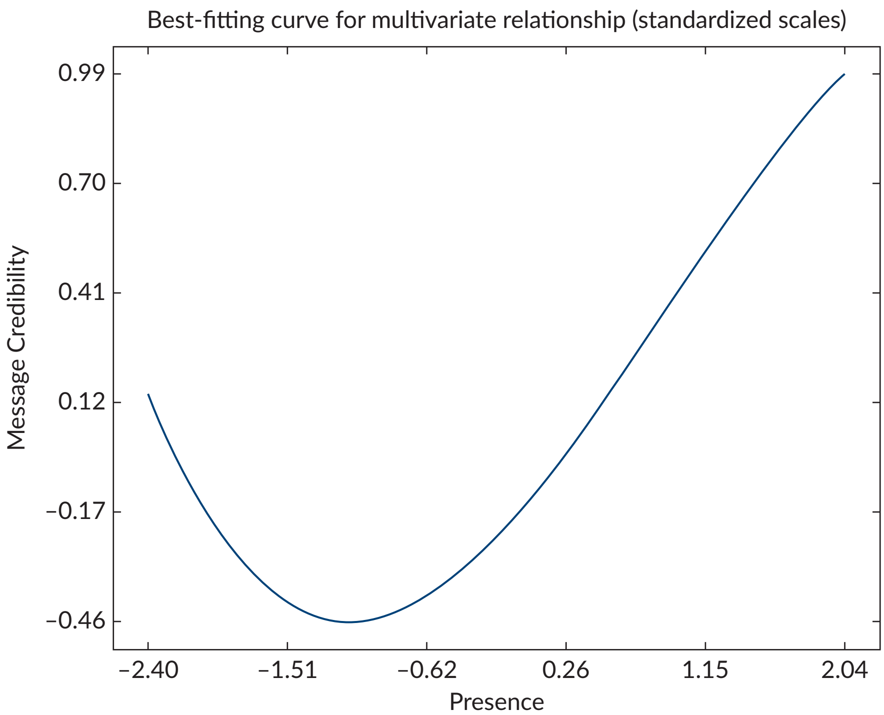

Figure 2. Curvilinear association between presence and message credibility.

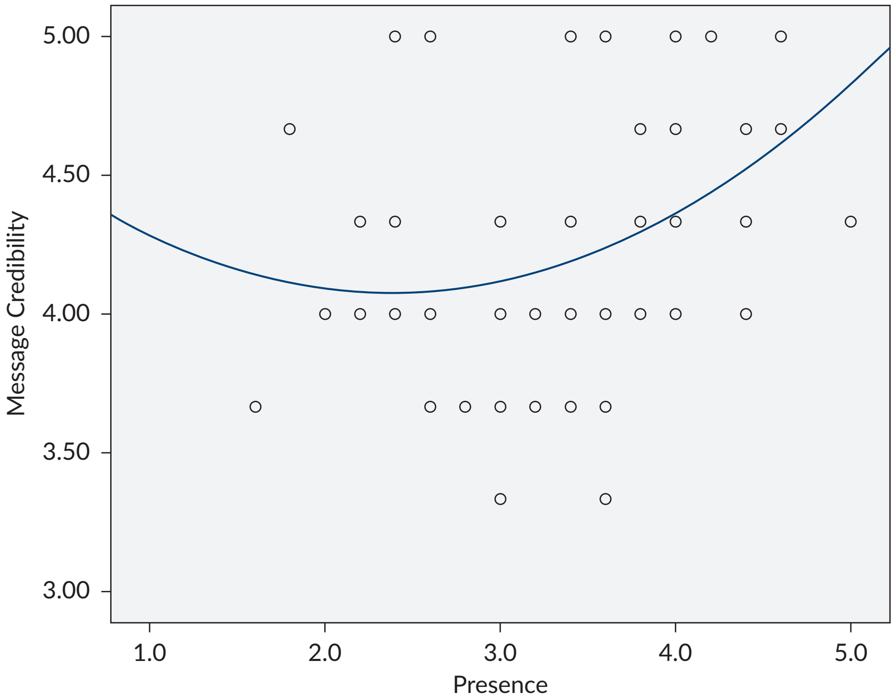

Figure 3. Scatter plot: Unstandardized relationship between raw scores of presence and message credibility. Note: The curvilinear line represents the cubic relationship estimated between presence and message credibility.

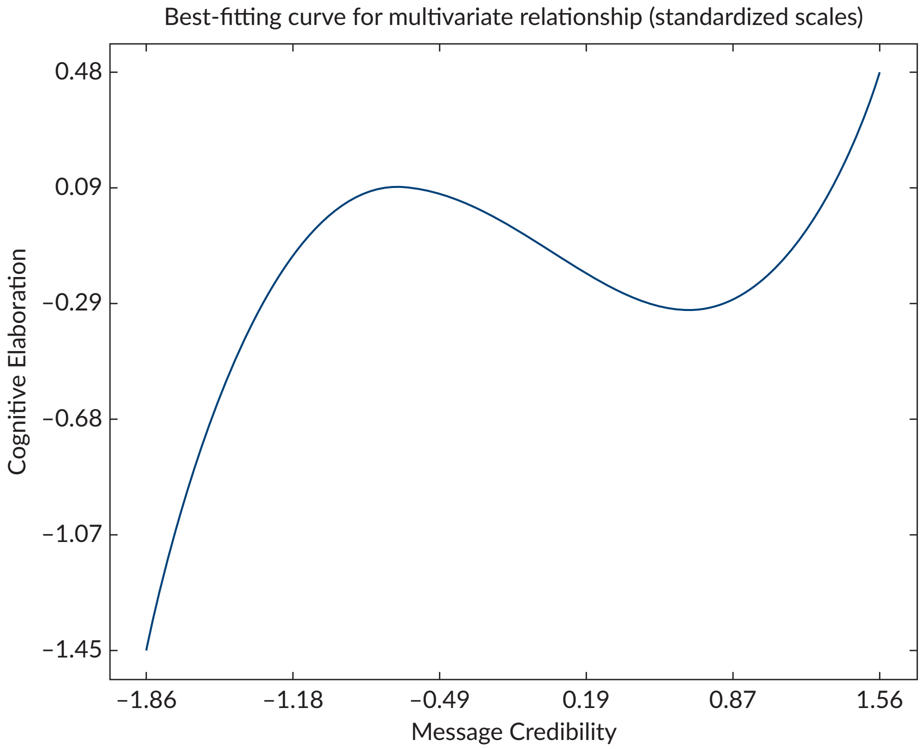

Figure 4. Curvilinear association between message credibility and cognitive elaboration.

is positively, yet curvilinearly, associated with cognitive elaboration (β = .36, p = .001). Notably, need for cognition as a covariate had a positive significant effect on cognitive elaboration (β = .27, p = .01). Together with need for cognition, the evaluation of message credibility explained 16% of the variance in the cognitive elaboration (R^2 = .16). In sum, H3 was supported.

H4 predicted that the valence of thoughts generated via cognitive elaboration would have a positive yet curvilinear relationship with behavioral intention to engage with pro-environmental behaviors. As predicted, PLS-SEM estimated a non-linear relationship between the variables as the best solution (see Figure 5), demonstrating that the valence of thoughts generated via cognitive elaboration had a significant curvilinear relationship with behavioral intention to engage in pro-environmental behaviors (β = .25, p = .02). However, the pattern of the curvilinear relationship was different from our prediction. Therefore, H4 was not supported. The cognitive elaboration explained 6% of the variance in the intention to engage in pro-environmental behavior (R^2 = .06). Figure 6 shows the results of the non-linear model estimated by PLS-SEM.

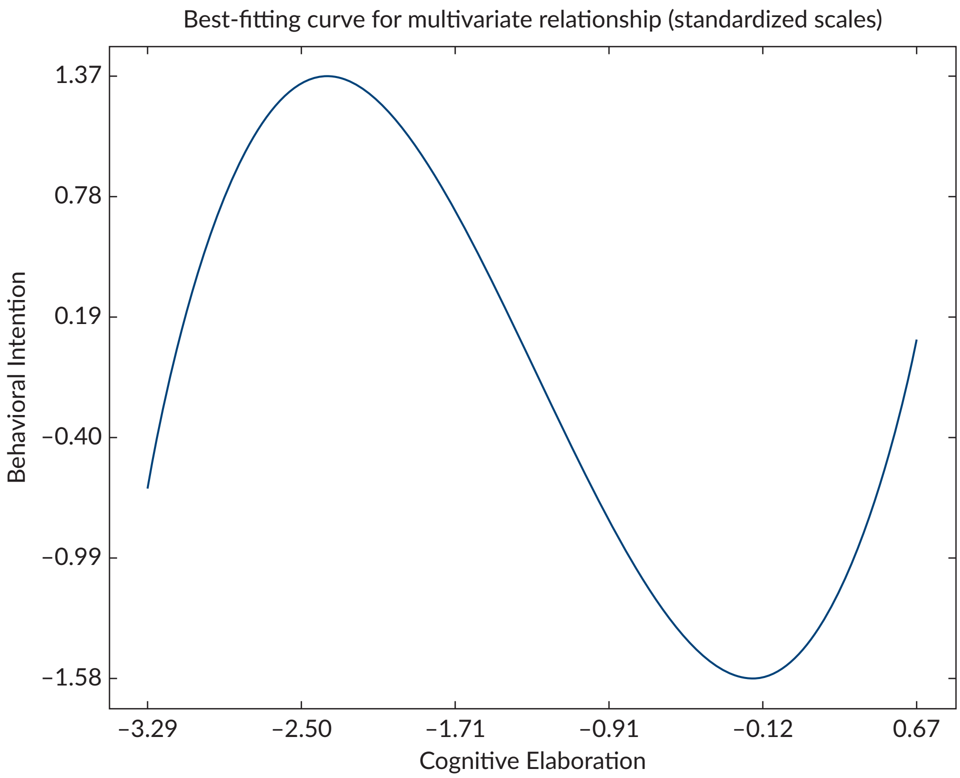

Figure 5. Curvilinear association between cognitive elaboration and behavior intention.

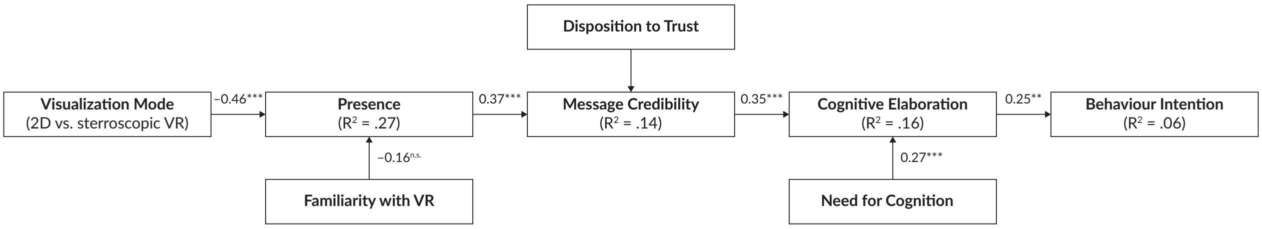

Figure 6. Results of non-linear PLS-SEM model. Notes: * $p < .05$; ** $p < .01$; *** $p < .001$; n.s. = not significant.

4.3. Model Fit

For evaluating the fit and quality of the proposed model, we primarily tested the following: (a) the average path coefficient, (b) the average R-squared, (c) the values of the average variance inflation factor, and (d) the average full collinearity variance inflation factor. These are suggested as classic model fit and quality indices to be tested in PLS-SEM (Kock, 2022). The results of the PLS-SEM indicated that the proposed non-linear model had a better fit compared to the linear model. Details regarding the criteria for evaluating model fit and quality indices, as well as additional indices, are provided in Table 4.

Table 4. Model fit and quality indices.

	Criteria	Linear model	Non-linear model
Average path coefficient	$p < .05$	.198 ($p = .026$)	.274 ($p = .006$)
Average R-squared	$p < .05$	.103 ($p = .103$)	.157 ($p = .051$)
Average variance inflation factor	≥3.3	1.071	1.055
Average full collinearity variance inflation factor	≥3.3	1.274	1.274
Tenenhaus goodness of fit	medium ≥.25; large ≥.36	.270	.334
Simpson's paradox ratio	≥.70	.857	1
R-squared contribution ratio	≥.90	.994	1
Statistical suppression ratio	≥.70	.714	.857
Nonlinear bivariate causality direction ratio	≥.70	.786	.786

5. Discussion

5.1. Discussion of Findings

Overall, our study suggests the complex nature of understanding the persuasion processes underlying the use of immersive media. Although the results of PLS-SEM demonstrated that most of the hypotheses were supported, the goodness of model fit was highest when a non-linear relationship between presence, message credibility, cognitive elaboration, and behavioral intentions was estimated. These findings underscore the importance of considering the cognitive dynamics underlying persuasion processes and the use of immersive technologies.

In support of our prediction, the results of our study confirmed that 360-degree videos visualized through a VR HMD indeed induce a greater sense of presence than traditional 2D videos. This finding adds to the validity of previous studies, which have also found a superior capability of 360-degree videos in inducing a greater sense of (spatial) presence (Amrhein & Balaban, 2024; Breves & Heber, 2020; Fraustino et al., 2018; Oh et al., 2020). Furthermore, this finding advances the existing conceptualization and knowledge on the role of 360-degree videos, as our study controlled for interactivity by allowing participants in the 2D video condition to also interact with 2D content (i.e., switching perspective, zooming) via dragging and spanning using the mouse. The findings of our study suggest that the immersiveness of 360-degree videos viewed through a VR HMD, determined by the combination of both vividness and interactivity (Steuer, 1992), significantly enhances users' sense of presence.

Interestingly, a threshold effect was found in the relationship between presence and subsequent message evaluations (i.e., credibility perceptions). Specifically, we observed that credibility evaluation increased significantly only when the sense of presence surpassed a certain threshold (see Figure 2). This nonlinear relationship highlights the nuanced interplay between immersive technologies and user responses, challenging conventional linear models. This finding suggests that users may begin evaluating immersive experiences positively and linearly only when the subjective rating of presence reaches a point close to the midpoint of a 5-point Likert scale (i.e., approximately 2.5). Based on this finding, we may speculate that perceptual evaluation of media experiences, including immersive storytelling, may ensure positive perceptions from users upon successfully eliciting at least a moderate sense of presence. In other words, our findings suggest that a non-careful integration of presence-evoking technologies or design of immersive content may lead to a boomerang effect, resulting in users rating their experience and messages rather poorly upon the failure to induce at least a moderate sense of presence. Nonetheless, the overall linear trend found between presence and message credibility is in line with previous findings drawn from the modality, agency, interactivity, and navigability model (Sundar, 2008), as well as the relationship predicted in the four-step model of persuasion (Breves, 2023) adopted as a framework for this study. Our finding also supports the idea that the detrimental effect of adding the 360-degree feature to photography on message credibility (Greussing, 2020) could have been caused by the unnatural mapping of a static image with a dynamic and interactive feature. Although the relatively small sample used in our research raises some concern regarding the influence of outliers on the curvilinear relationship between the sense of presence and message credibility, the assessment of the scatter plot (Figure 3) and the results of the box plot analysis mitigate this concern.

Contrary to linear assumptions, we found that the valence of cognitive elaboration (i.e., the consistency of message-relevant thoughts) shows a curvilinear relationship with credibility evaluation under specific conditions, suggesting the sensitivity of human cognition to the message's quality. The curvilinear relationship between message credibility and cognitive elaboration suggests that as the consistency of message-relevant thoughts increases, there may be a slight congestion upon reaching an interval where participants had rated the message as quite strongly credible, yet not to a full spectrum (see Figure 4). Nonetheless, the overall picture of this finding aligns with the proposition of Breves (2023) and her previous findings (Breves, 2021), demonstrating the sensitivity of valence and the amount of cognitive elaboration in response to message evaluation, as proposed by the bias hypothesis of the heuristic-systematic model (Chaiken & Maheswaran, 1994).

The observed fluctuations in behavioral intentions further underscore the complexity and challenges in predicting behavioral responses to persuasive messages. The curvilinear relationship between the valence (consistency) of cognitive elaboration and intention to engage in pro-environmental behaviors, visualized in Figure 5, demonstrates that the intention to engage in pro-environmental behaviors starts to drop and then only begins to increase again when the valence of message-relevant thoughts almost reaches the positive end of the cognitive elaboration continuum. While this finding may seem complicated to interpret, the curvilinear pattern suggests that an increase in thoughts consistent with the persuasive message might have led participants to remain defensive towards accepting the message (i.e., their intention to engage in pro-environmental behaviors) due to the relatively weak argument quality provided in the persuasive content.

It is worth noting that the spherical content used for our experiment presented information indirectly (e.g., depicting the efforts of scientists and politicians to protect Palau, showing the damaged coral reefs), rather than conveying direct or strong messages in an attempt to persuade. Considering that argument quality is suggested as an important factor in predicting the valence of cognitive elaboration and subsequent behavioral intentions (Breves, 2023), this finding suggests that the weak argument quality might have led people to hesitate from engaging in pro-environmental behaviors even when their thoughts had increasingly become consistent with the message. Nonetheless, the graph shows that when the valence of thoughts has almost reached the end of the positive spectrum, behavioral intention begins to increase again as a result of biased processing of information. This finding emphasizes the importance of taking into account the role of message quality, as suggested by Breves (2023).

5.2. Implications

Our study suggests several theoretical and practical implications. First of all, by elucidating the threshold effect of presence and the intricate dynamics of heuristic evaluation and information processing, the current study offers valuable insights into the design and evaluation of immersive technologies. For example, our study highlights a previously overlooked aspect in presence research: the non-linear effects of presence. While previous researchers have shown limited interest in the possible non-linear effects of presence on user perceptions, our study emphasizes their significance. This finding underscores the importance of considering both linear and non-linear effects of presence in the research and design of presence-evoking technologies and content. By recognizing and understanding the threshold effect of presence, designers can develop more effective strategies for creating immersive experiences that elicit positive evaluations from users. This implication emphasizes the need for a nuanced approach to designing immersive technologies, taking into account the complex interplay between presence and user experience. Moreover, our study also provides insights into understanding the relatively overlooked curvilinear relationship between cognitive elaboration and behavioral intention within the realm of social scientific research. This finding presents an opportunity for future researchers to explore the nuanced relationship between cognitive and behavioral constructs.

Another implication pertains to the fact that our study validated the robustness of the four-step model of persuasion by spatial presence (Breves, 2023). Our findings suggest that the novel framework could serve as an overarching guide applicable across various domains, from education to environmental communication and beyond. The findings of our study, based on the framework, offer meaningful guidance on leveraging immersive technologies for storytelling. Specifically, our study suggests that a proper use of immersive technologies such as 360-degree videos may prompt audiences to positively think along with the message due to the activation of positive heuristics related to the sense of presence. By providing a roadmap for leveraging immersive storytelling for effective communication strategies, our research offers practical insights for practitioners across various domains.

5.3. Limitations and Future Directions

Despite the significant contributions of our study, it is essential to acknowledge its limitations. One such limitation concerns the lack of control for issue involvement and prior attitudes towards climate change. Previous studies employing the heuristic-systematic model (e.g., Breves, 2021) have demonstrated that issue involvement, or the personal importance of an issue, could potentially influence user evaluations of immersive content and subsequent information processing. Similarly, participants' prior attitudes towards climate change may influence their reactions and evaluations. Although none of the participants in our experiment indicated prior knowledge of the climate change issue in Palau, which mitigates concerns related to not measuring issue involvement and prior attitudes to some extent, future researchers would benefit from measuring and controlling such variables to ascertain the validity of our findings.

Additionally, it is important to acknowledge that the subjective nature of the thought-listing technique (Cacioppo & Petty, 1981) used in our study should not be considered free from potential biases or inconsistencies in data coding, although the significant inter-coder reliability calculated in our study resolves these concerns to some extent. Notably, while the current study adopted the original methods of coding the mode of information processing suggested by Cacioppo and Petty (1981), Breves (2021) suggested a relatively new approach called "subjective rating" to address issues related to low inter-coder reliability and mis-coding of information (i.e., having participants rate and count the number of their thoughts). Future researchers may consider adopting the subjective rating method to confirm if the findings of our study remain the same and also to address inter-coder reliability issues. Additionally, albeit costly, future researchers may also consider employing psychophysiological measures to add objective evidence and ensure the validity and generalizability of our findings.

Moving forward, we suggest that future researchers explore additional factors that may moderate the effects observed in our study. One avenue for future investigation involves comparing the effects of immersive storytelling through 360-degree videos with that through VR content. Acknowledging that VR content allows for a greater amount of interactivity within the virtual environment, thus offering a greater possibility to engage with the content (as in Cho & Park, 2023; Pimentel & Kalyanaraman, 2023), future researchers may consider examining if conveying the same messages via VR content will induce a more positive impact on user perceptions and persuasion than that via 360-degree video contents. Through this investigation, we would be able to better understand if the efficacy of employing 360-degree videos for storytelling would be comparable to that of VR content and indeed be regarded as an effective alternative to VR content, which is considered less affordable and accessible than 360-degree video content.

Nonetheless, recent studies (e.g., Ahn et al., 2022) often demonstrate that VR content may induce a negative impact on user cognition and information processing. The cognitive theory of multimedia learning (Mayer & Moreno, 2003) suggests that the novel stimuli signaled within the virtual environment can lead users to allocate cognitive resources in processing surrounding information using multisensory systems, thereby depleting the available cognitive resources to process central messages. Such findings imply the possibility that the virtual nature of VR content may result in an inferior effect on persuasion compared to 360-degree video content. Future researchers may conduct a comparative study to ascertain if immersive storytelling via 360-degree video content could indeed be an effective alternative to VR content by reducing the cognitive load imposed by virtual elements in VR content. Building on this notion, future researchers may further explore whether the combination of 360-degree and VR content (i.e., similar to mixed-reality content) may overcome the negative aspects of using VR content for storytelling.

Lastly, although our study's sample size was justified based on a power analysis, we recommend that future researchers use a larger sample size to verify whether the curvilinear relationship among the variables in our study holds true. It is noteworthy, however, that our findings align well with those of recent studies that employed either larger (e.g., Amrhein & Balaban, 2024; Meijers et al., 2023) or similar sample sizes (e.g., Behm-Morawitz & Shin, 2024; Breves & Heber, 2020) to compare the effects of 360-degree videos or VR content with 2D videos or traditional media (e.g., text-based articles). This suggests that recent immersive media are robust compared to traditional media in inducing positive user perceptions. Given this implication, we encourage future researchers to explore potential moderators that could amplify or diminish the impact of immersive technologies on user perceptions and behaviors. Such exploration could provide deeper insights into how we might better leverage immersive media technologies for storytelling.

Conflict of Interests

The authors declare no conflicts of interests.

Data Availability

The data and supplementary materials used in this study are available at https://osf.io/2yzrk/?view_only=aa6ef8cd78d84d75a1851246526d4f9c

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XR for Transformable and Interactive Design

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Abstract

This article aims to show the applicability and evaluation of a teaching-learning method based on user experience (UX) design and extended reality (XR) in architectural studios. In the summer of 2023, the XR Assisted: Transformable and Interactive Design studio utilized the UX+XR teaching-learning method. During the studio, the emphasis was on designing a transformable and interactive architectural installation, with the UX as a center and XR, artificial intelligence, and inmotics as design and visualization tools. In the UX+XR method, the users were the students, and each student designed transformable architecture by applying UX strategies to their specific urban installation users. The UX+XR method had four phases. Each phase incorporated a cross-strategy UX+XR during the design process stages. Using UX+XR, the participants designed an architectural installation where the concepts of transformability, ephemerality, interactivity, flexibility, adaptability, versatility, and playfulness were present. Based on testing the six architectural installations designed during the studio using the UX+XR method, our data showed that XR enhanced the designer's perception, constituted a new means of expression on an accurate scale, and is a highly immersive and interactive resource for communicating ideas and reinforcing visualization, simulation, stimulation, and interaction. XR is a powerful tool that, as used in the designed method, allows an elevated level of visual communication, understanding of spatial dimensions, and an effective multi-user collaborative strategy for evaluating the designed proposals.

Keywords

artificial intelligence; extended reality; inmotics; interactive architecture; transformable architecture; user experience

1. Introduction

This research evaluates a teaching-learning environment that implements user experience (UX) design and extended reality (XR) for transformable and interactive architecture within an XR-assisted studio at the School of Architecture and Urban Planning at the University of Wisconsin – Milwaukee (SARUP-UWM).

We developed a comprehensive method that combined UX with XR, including artificial intelligence (AI) and inmotics as technological resources for automation and interaction. This method consisted of four phases, integrating UX and XR strategies to improve the architectural design process.

This study proposes a fusion of AI and XR to establish a typology of interactive design for user-responsive installations. Consequently, it challenges researchers and designers to leverage digital technology in crafting immersive and meaningful experiences.

The XR Assisted: Transformable and Interactive Design studio was a 6-unit credit workspace that enabled participants to design by implementing the UX+XR method as a supported strategy to enhance perception, visualization, simulation, and collaboration during the design process. This studio focused on improving UX in architectural spaces, emphasizing inclusion and accessibility. The students were required to design a transformable architectural product that responds anatomically and functionally to the diversity of movements and anthropomorphic measurements of the user and generates a sensory-emotional system that stimulates the creation of intimate and collective memories.

XR improves our perception of the tectonic environment through synthetic environments. Various innovative technologies have transformed practices over time in the architecture, engineering, and construction industry. These advancements include hand-drawn drawings, physical models, computer graphics, multi-dimensional digital models, and building information models. Recently, the rapid development of extended reality (XR) technology has further revolutionized the architecture, engineering, and construction industry. XR has the characteristics required for solving distance, space, and time constraints that we cannot complete with traditional design strategies (Chi et al., 2022). Assisted with external devices, XR permits the experience and stimulation of the senses through the digital recreation of scenarios and establishing a remote and synchronous collaborative design environment (De La O Miranda & Cortés Campos, 2023).

When working with XR, it is essential to incorporate UX strategies. Key verbs for success include travel, discover, perceive, interact, navigate, and feel. These verbs are crucial for an efficient UX predesign in digital and physical experiences.

The UX+XR strategy allows the designer to recreate what the potential user can feel and assess the design's spatial qualities on an accurate scale. Through XR, it is possible to superimpose the digital design in the physical context using augmented reality (AR) or mixed reality (MR). This allows us to identify environmental relationships, proportions, and functionality. When implementing UX strategies in the architectural process, the user studies the anatomy and spatiality of their contextual elements, both individual and collective.

The benefits of AR and virtual reality (VR) in education are increasingly becoming evident across various fields. In 2019, 436 AR/VR education studies were submitted to the Web of Science (Garzón, 2021). These studies have reported several advantages for students, which include improved information retention, enhanced visualization abilities, increased attention and motivation, improved outcomes and success rates, facilitated access to a psychological "flow" state, and collaborative benefits (Pinter & Siddiqui, 2024). Interactive 3D models allow students to manipulate and explore complex concepts hands-on. AR and VR technologies can transform education by offering interactive and immersive learning environments that boost student/teacher skills, understanding, and knowledge retention (Allcoat et al., 2021; Anwar et al., 2023).

2. Fundamentals to UX, User-Centered Design, and XR as Formal Evaluation Method in Teaching-Learning Environments

2.1. UX Essentials: User-Centered Design, Accessibility, and Usability

"User experience" was coined in the 1990s by Don Norman, co-founder of Nielsen Norman Group, a leading consultancy in UX design. It encompasses all aspects of user interaction with an ecosystem, environment, device, or service. The UX method emphasizes user involvement before, during, and after design. It has a qualitative focus and aligns with the agile "design thinking" process (Aguirre-Villalobos et al., 2023; Garrett, 2011). The UX method implies the following stages:

- Empathize: Understand users and investigate their pains, hopes, and habits in relation to the ecosystem in which they operate;
- Define: Research users and synthesize solutions to propose answers;
- Ideate: Generate project ideas based on user research;
- Prototyping: Generate high, medium, and low fidelity models to obtain user feedback;
- Testing: Evaluate how users perceive both physical and digital models and measure their effectiveness.

The process is a non-linear iterative model. With each change, users can generate opportunities in the maturity of the project or services (Mootee, 2013; Osterwalder et al., 2013).

The UX method focuses on understanding user interaction with products or services and enhancing their functionality and user satisfaction. It is systematic, participatory, and iterative, involving the user in all research and final development stages. Based on user-centered design, UX considers accessibility and usability central aspects (Aguirre-Villalobos et al., 2024; Gallagher & Getto, 2023).

User-centered design is a discipline that prioritizes users' needs and experiences in the design process. In the context of digital technology such as XR, AI, and inmotics, user-centered design ensures that these technologies are accessible, intuitive, and satisfying for users. It guides the design and implementation of digital solutions and ensures that the product of design seamlessly integrates into users' daily lives through research, testing, and continuous improvement (Aguirre-Villalobos et al., 2021, 2023).

2.2. XR as a Teaching-Learning Environment

The following section presents fundamental concepts and perspectives about integrating XR tools in education, focusing on architectural studies and complementary technologies such as inmotics (automation) and AI. These tools facilitate immersive learning, support the creation of transformable architectural spaces, and optimize data-driven learning. Furthermore, we identified several XR applications designed to create dynamic environments that respond to users' needs. This exploration considered a range of academic approaches and perspectives regarding their deployment.

XR implies different digital realities, with "X" as a placeholder for any form or new reality. This concept encompasses using XR as an abbreviation for xReality (Rauschnabel et al., 2022). XR is the frame that includes multiple types of new digital realities, like VR, AR, MR, virtual 360-degree tours, and immersive technologies tools, to simulate and enhance the perception in synthetic environments, where the "X" implies the unknown variable. In "xReality," thus, "X" indicates "all" new reality formats (Rauschnabel et al., 2022).

XR in learning processes has a valuable positive impact on the learners. It democratizes experiential learning, creates an overlay of data and knowledge, and increases student productivity. VR-based education involves wearing a headset or using other devices to experience a simulated 3D environment with which users can interact. Immersive learning involves a broader range of technologies, including VR, AR, MR, and other interactive environments (Abd El-Latif et al., 2023).

To define MR, we adopted the concept proposed by Rauschnabel et al. (2022), who present a continuum where MR is between AR and VR, with the natural world and VR at opposite ends. Unlike Milgram et al. (1995), they do not conceptualize MR as a general term but as a specific reality that "combines the real with the possible" (Farshid et al., 2018). Similarly, Flavián et al. (2019) describe "pure mixed reality" as a technology between augmented reality and augmented virtuality (Ortega Rodríguez, 2022; Panko, 2023).

VR encompasses diverse, immersive learning environments that administrate educational content, enhance comprehension, and establish secure virtual laboratories within various educational domains, including healthcare, engineering, science, and general education. Educational materials, particularly those related to the anatomical structure and functions of human organs or the cosmos, are challenging to grasp through textual means alone. VR technologies can facilitate comprehension and offer sustained opportunities for practice and experiential learning (Anwar et al., 2023; Petit et al., 2022).

VR solutions are effective in various educational settings and are well-received by students (Anwar et al., 2020; Huang et al., 2010; Kiss, 2012; Panteldis, 2009). VR implementations typically require user input or interaction, which promotes active engagement over passive learning approaches. The concept of virtual reality learning environments (VRLEs) revolves around providing students with immersive 3D environments with which they can interact. Although existing studies have shown positive student perceptions of VR in education, they emphasize the importance of incorporating a solid pedagogical foundation in any meaningful educational innovation (Huang et al., 2010). Over the past few years, VR has gained significant attention for its potential to revolutionize education. A growing body of research examines the use of VR in improving students' cognitive skills in various educational contexts, including science, technology, and engineering (Anwar et al., 2023). AR and VR represent potent tools for accessing and assimilating precise information when it is most opportune. AR and VR enhance learning by simulating real-life experiences that evoke emotions or allow users to experience someone else's story. These technologies are highly valuable for a wide range of users and sectors (Chu & Ko, 2021; Ramos Aguiar & Alvarez Rodriguez, 2024; L. Wang, 2022; Z. Wang et al., 2024).

2.3. XR Applied to Education in Architectural Studies

In educational usage of XR, especially for architectural studios, the UX experience must be considered a parameter to facilitate the project process and effectively design based on user needs. When interacting with a designed space or urban context, UX results from a person's perception of that designed space, or context. UX can be used by a collective defined by human and non-human relationships involving the natural or urban ecosystem and has a participatory and inclusion objective (Aguirre-Villalobos et al., 2021).

The designer—in this instance, the student—should be able to effectively observe and interpret, as delineated by the stages of UX Empathize and Define. The designer must understand the users' challenges and expectations to integrate the contextual circumstances that address the collective user needs. This process involves collaboration with other designers within the group to establish operational systems (Ferrer-Mavárez et al., 2020).

2.4. Incorporating AI and XR to Enhance Data-Driven Learning

With XR, AI can enrich how machines learn from data without heavy programming, leverage statistical learning techniques to predict attributes, and attain progressive learning capabilities that accommodate and analyze new data. AI can bridge the gap between simulation and reality. With AI strategies, developers can create high-quality holographic images that look good on LCD screens (Gergana, 2022). The potential of incorporating AI and XR as part of space systems promises a more efficient performance, especially useful for creating responsive urban installations and learning spaces for users with specific characteristics (Marín-Morales et al., 2018; Mehta & Singh, 2024).

XR utilizes computer-generated virtual environments to enhance human capabilities and experiences, facilitating more effective learning and discovery skills. On the other hand, AI attempts to replicate how humans understand and process information (Loshin, 2013; Rauschnabel et al., 2022; Romero Morales et al., 2010) and, combined with a computer's capabilities, process vast amounts of data without flaws.

In the United States, after the oil crisis of the 1970s, the primary objective of generating savings in consumption was to avoid expenditure (Romero Morales et al., 2010). After the first automation, air conditioning and intruder control systems, i.e., alarm systems, were developed. The discipline of researching and developing this technology was called "home automation."

Home automation—in this article, "domotics"—has a genesis analogous to "informatics," replacing the prefix that means information with another derived from the Latin word "domus," which means house. The root of the word "domotics" is the sum of "domus" and "tics." The term "domotique" (from French) is noteworthy for its association with robotics (Domotique, n.d.). In this way, home automation or "domotics" is robotics applied to construction. When addressing non-residential tertiary structures, "building automation" becomes pertinent. This discipline is primarily concerned with energy management, encompassing the automation of tasks and operations (Chi et al., 2022; Romero Morales et al., 2010).

This research proposes AI, building automation, and XR technology to generate interactive architecture where the space contains elements responsive to users' needs. For this article, inmotics is defined as a building automation system: "An inmotic system is a network that controls, supervises, and optimizes devices and agents in charge of managing different building areas; thus, each component performs its function automatically without leaving the centralized control" (Strauch-Gómez et al., 2017). The potential of incorporating inmotics, AI, and XR into space systems would be beneficial for creating transformable architecture for users with specific characteristics (Calderón Zambrano et al., 2023).

2.5. Towards Transformable Architecture Through the Integration of an Adaptive System

In this research, transformable architecture is defined as incorporating a responsive system that enables the modification of the envelope or components within an architectural space according to the users' needs. Transformable architecture can create an innovative and dynamic space in which users have more opportunities to change their surrounding environment effectively. It also opens a way to meet environmental needs and respond to unexpected situations (Asefi, 2012). When discussing transformability, two or more features or systems work together to produce a specific change in the architectural space grounded on transformation principles. The principles of transformation encapsulate the physical and perceptual reconfiguration of internal spatial layouts and membranes (Andjelkovic, 2016). This is accomplished by manipulating design elements, involving opening and closing, expanding and contracting, joining and dividing, and pulling in and drawing out. The alteration of disposition, shape, or structure leads to the desired transformation. This process is primarily accomplished through the rotation, translation, and combinations of rotation and translation of primary or complex (spatial) geometric elements.

The symbiosis of transformability and technologies within the multiple dimensions of contemporary design generates a technological system, a design strategy, and a defined typology of digital technology and architectural tectonics—a form of living architecture as the envelope or second skin between the human and its habitable context. The design of each skin is as unique as its users and implies infinite solutions for specific users. In addition, this methodology and typology of architectural spaces could respond to multiple programs: interior design, urban and public spaces, educational, temporary architecture, medical, residential, commercial, recreational, historical, and tourism. This symbiosis was one of the leading design objectives during the XR Assisted studio at SARUP-UWM.

2.6. Evaluation: Framework and Essential Aspects for Evaluating a Teaching-Learning Environment Implementing

UX+XR It was crucial to consider both the UX and the learning outcomes to evaluate a teaching-learning environment that integrates UX and XR. According to Kim et al. (2020), a systematic review of VR systems highlights the importance of usability, immersion, and user satisfaction, which directly influence the effectiveness of XR environments for learning. Usability also involves emotions and how the user creates and develops the experiences. Effective computing can improve interaction in XR, helping to adapt the experience to the user's feelings and needs and increasing its effectiveness in educational contexts (Ferrer-Mavárez et al., 2023; Guo et al., 2020).

In his work, *The Design of Everyday Things*, Norman (2013) highlighted the importance of usability and UX in designing digital interactions. In addition, Aguirre-Villalobos et al. (2024) propose that effective learning comes from direct interaction in the design process of the usable environment and the value of implementing tools that align with the use of XR for teaching. Regarding implementing XR technologies in education, Jacobsen et al. (2022) show that the experience in virtual environments can be as practical as in physical environments, highlighting the validity of using XR in teaching. These studies agree that evaluating the UX in XR should focus on personalization and intuitive interaction effectiveness to facilitate collaborative learning. In evaluating immersive experiences in VR environments, they emphasize the importance of usability, immersion, and feedback in creating effective learning strategies (Beqiri, 2016; Jacobsen et al., 2022).

It was crucial to consider the critical aspects related to the user in the context of the xReality-assisted design process. This approach was essential for evaluating the effectiveness of employing UX combined with XR in the instruction of architectural design. The key aspects are delineated as follows:

- Usability: How users interact with the virtual architectural environment, ensuring that navigation is intuitive and efficient;
- Interaction and immersion: The ability of users to interact with human-scale virtual space at a prominent level of realism and whether the environment generates an adequate sense of presence and immersion;
- Accessibility: Ensure the design is inclusive and accessible to users with different navigation and interaction abilities;
- Sensory feedback: Evaluating the appropriate use of visual, auditory, and haptic stimuli to improve the understanding and experience of space;
- User satisfaction: Assessing users' holistic satisfaction regarding comfort, aesthetic appeal, and functionality within the architectural context;
- Learning effectiveness: How the XR environment facilitates spatial understanding and the assimilation of complex architectural concepts.

When evaluating a teaching-learning environment that combines UX and XR, it is essential to consider:

- User engagement: Evaluate the level of attention, interest, and motivation that the XR learning environment generates in students;
- Knowledge retention and transfer: Measure the effectiveness of the experience in assimilating and applying complex concepts in architectural design;
- Feedback and personalization: The system's efficiency in adapting the content and providing feedback in real-time to improve learning;
- Efficiency and fluidity of interaction: The tools and functionalities enable an efficient and seamless UX during the teaching process;
- Learning outcomes assessment: Assess the alignment between pedagogical objectives and their achievement through the XR platforms, measuring technical and comprehensive skills;
- Technological adaptability: The degree to which the XR environment adapts to different devices and technologies without compromising the UX.

3. Method

Our project focused on integrating XR and UX stages to improve the architectural design process and optimize teaching-learning environments centered on users' and designers' needs. To achieve this integration, we identified the layering stages among the phases of the UX design process, the architectural design process, and the XR tools as facilitators in the spatial design process (Figure 1).

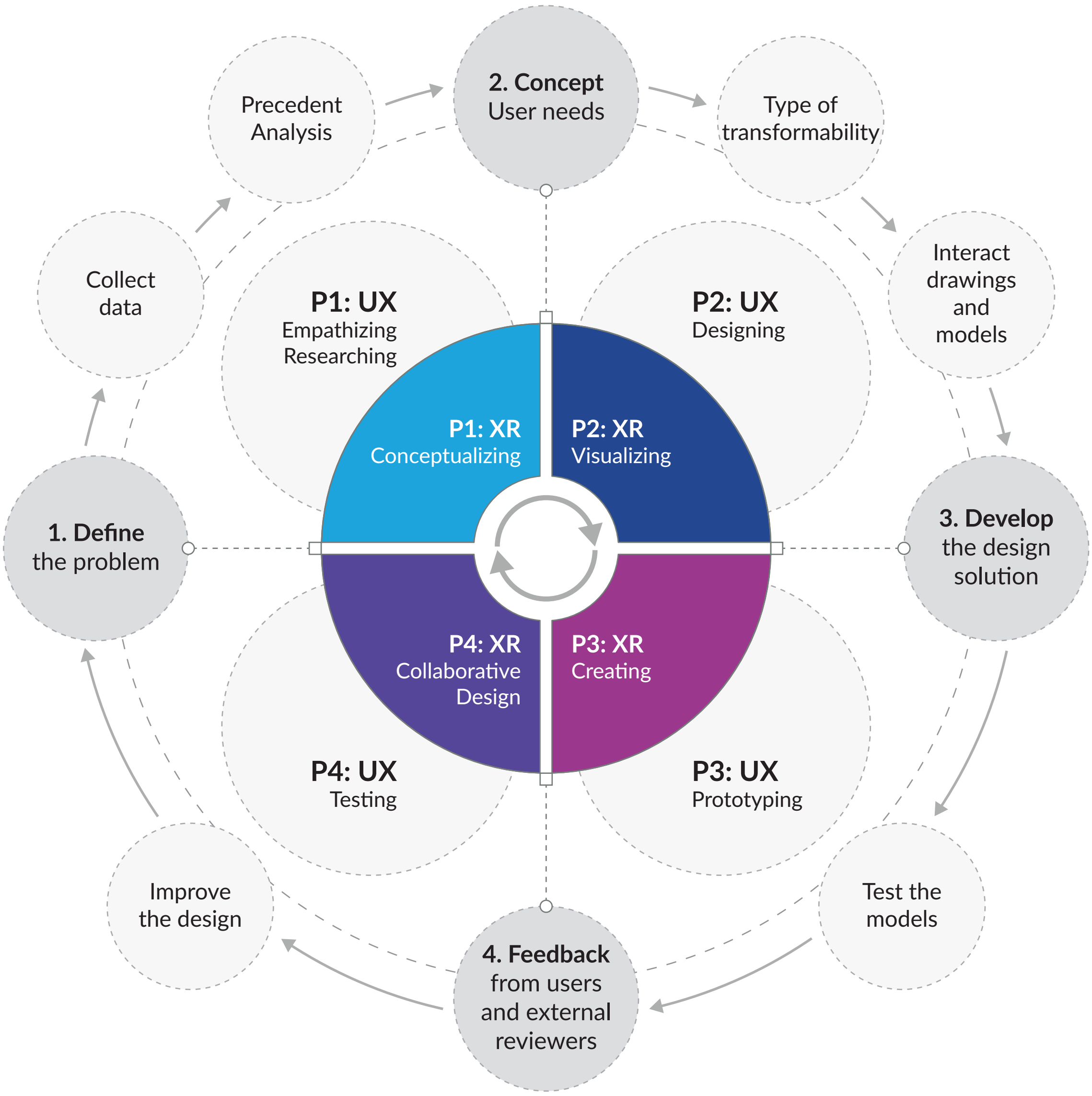

Figure 1. UX+XR method in architecture design studios.

To develop the UX+XR method, we formed a transdisciplinary team of UX, XR, transformable architecture design, and inmotics experts to lead an intensive summer architecture studio with juniors, seniors, and graduate students to apply and assess the UX principles implementing XR during the design process. Due to the complexity of the design problem and the process involved in using XR, it was necessary to allow upper-level students to participate in the student range.

3.1. Participants

This research was part of a collaborative project involving three universities from different countries: the United States, Chile, and Argentina. This project was led by an international team composed of an academic researcher and an IT assistant from SARUP-UWM in collaboration with a UX expert consultant from the Escuela de Arquitectura de la Universidad Tecnológica Metropolitana in Chile, and a building automation expert from the University of Cordoba in Argentina.

We established a methodological model based on UX design and using XR. This approach focuses on comprehensive qualitative data analysis to develop an academic proposal (Martinelli et al., 2024). The research was conducted in the context of a 90-hour workshop in the architecture program at SARUP-UWM. This workshop serves as the setting, data source, and academic framework for the methodological implementation during the design process.

During the first studio phase, the students had to identify social issues in Milwaukee and devise adaptable design solutions utilizing UX+XR, inmotics, and AI technologies. This qualitative, inductive approach focused on understanding phenomena through collecting and analyzing unstructured data. Techniques include participant observation, semi-structured interviews with students during UX+XR methodology implementation (Aguirre-Villalobos et al., 2024), the use of observation notebooks in student projects (González et al., 2023; Montes Sosa & Castillo-Sanguino, 2024) and following UX+XR methodology stages to assess the applicability of the teaching-learning process by the lead course instructor (Rodrigues de Andrade, 2023).

3.1.1. Population and Data

Data consisted of semi-structured qualitative interviews conducted between June and July 2023 with young students aged 22 to 25, all enrolled in the architecture program at SARUP-UWM in the XR Assisted studio. Of the 11 interviewees, five identified as female and seven as male.

3.2. Design

Throughout the research process, students applied UX+XR for transformable and interactive design in architecture, creating diverse projects such as urban mental health stations, interactive parks, housing for the homeless, climate-adaptive bus stations, urban educational spaces for children, and public baby feeding spaces.

The strategy to design transformable architecture within the UX+XR method implied the following steps: (a) identify the type of transformability that responds to the need or problem; (b) identify the elements of design that need to be transformed (skeleton, skin, shell fragments, etc.); (c) identify the type of materials and mechanisms that allow the desired transformation; (d) determine the transformation principles; (e) define the joins and articulators for transformability; (f) determine feasibility and human scale that activates and controls transformability; and (g) determine the inmotic and digital elements that trigger transformability and technical aspects.

By crossing UX+XR with AI and inmotics in architectural design, we achieved efficient solutions with diverse aesthetics and innovation focused on technology-assisted humans with interactive options to increase their quality of life. In this context, the XR Assisted studio aimed to involve students in cross-design processes that solved urgent societal problems in conjunction with the emerging digital design technologies overlapping

UX+XR+AI. This studio's approach showed the phases of UX and XR at specific moments in the design process, addressing multiple technological platforms for the virtual simulation of products. Students used their cell phones, computers, HTC VIVE, Oculus Quest 2, or Meta Quest 3 in the XR studio room during all the phases.

3.3. Procedures

The definition of the proposed methodological model phases resulted from overlapping the main stages of the architectural design process, the UX methodology, and the XR strategies proposed in architecture (Figure 1).

The studio was designed in four phases. The program consisted of two weekly classes, each lasting two weeks (see Figure 2). The first phase was UX Empathizing and Researching and XR Conceptualizing. In the first phase, the students clarified the users' problems and needs in the project's context. The students applied problem analysis, empathy mapping, and exhaustive research, including interviews and proto-persona creation.

Students created spatial and formal conceptualization design proposals using Tilt Brush, Gravity Sketch, and Twigital AR applications. Understanding the human scale was one of the most relevant advantages of using AR. This resource permitted us to explore the initial concept of design and create conceptual physical models into digital models by scanning the models and visualizing them using Twigital. Those apps allowed an interactive re-creation of architectural concepts, such as expandable space, flexibility, transformation, ephemerality, elasticity of space, and metamorphosis. This phase defined the user characteristics, context, program, and initial speculations about interactivity and transformability.

In the second phase, UX Designing with XR Visualizing, the students used mood boards, style guides, sketches, or visual models to introduce the user to the design image closest to the result. Next, the students used Enscape, Twinmotion, and Kuula to visualize the design in an elevated level of detail. In this phase, students defined the architectural components, materials, and diagrams for the AI or inmotics aspect. Students identified the strategy for transforming the design and representing the flexible space to define the interactive element in the installation and constructive process.

In the third phase, UX Prototyping and XR Creating, diverse prototypes were presented to users at various levels of fidelity, ranging from low to high, to receive their review and feedback on each at distinct stages of development. Prototype details were iterated in collaboration with users, refining them to ensure they felt comfortable and could be interacted with effectively. This phase focused on creating a physical prototype by building a model at 3/4" = 1'0" scale, using defined materials, and modeling structural joins at 1 1/2" = 1'0" scale. Students placed the ephemeral design on-site using AR. They created simulations and reviews during this phase, implementing Enscape, Twinmotion, and Twigital. Students also created a detailed construction manual.

In the fourth phase, UX Testing and XR Collaboration, the students evaluated the final prototype using collaborative testing techniques. Extensive testing identified issues or areas for improvement. Based on user feedback, design details were refined to ensure an optimal and satisfying experience. We evaluated the proposals in collaborative design environments using Arkio with external reviewers. Arkio served as a multi-user virtual and interactive platform for reviews. Students generated a collaborative virtual environment that could be experienced in real-time.

Figure 2. Example of design production per phase in the UX+XR method for transformable architecture.

3.4. Measures

Two evaluation stages developed from various data collection techniques were applied to progressively develop conjectural ideas (Hernández-Sampieri & Mendoza, 2018). We obtained our data from projects on transformable architecture using notebooks. Furthermore, we conducted interviews to assess the process's importance in student learning and comprehensive knowledge acquisition to evaluate the effectiveness of applying the UX+XR methodology in the project design phases (Buenaño et al., 2023).

This study utilized semi-structured interviews to evaluate the design process from students' perspectives. Architectural design requires meticulous process documentation, achieved through observation and the systematic recording of notes or feedback during studio sessions. Central to the architecture design process is decision-making aimed at resolving design problems that may have more than one possible solution, a task that can often be subjective. For this research purpose, documentation of this process was essential, requiring observation and detailed notes to be recorded in notebooks. The observation focused on the students' curiosity, the quality of their interactions, and the evolution of their ideas, with a particular emphasis on using UX+XR platforms. These platforms were used to visualize, communicate, simulate, and interact with architecture that can be transformed.

We designed and applied semi-structured interviews for the students to assess the UX+XR structure and flexibility. They allowed the exploration of previously defined topics while opening spaces for interviewees to delve deeper into unforeseen aspects. This technique is precious for capturing students' complex and subjective experiences in learning UX and XR, where interactions and emotions can influence their process of understanding and where students' subjective interactions and perceptions play a fundamental role in the learning process.

The observation notebook was vital in the XR Assisted: Transformable and Interactive Design project. It documented the findings, reflections, and adjustments during its development and detailed the creative and technical process. Evaluation measures included the coherence and comprehensiveness of the content, the reflective capacity, the applicability of ideas, the innovation shown, and the evolution of the project over time.

We implemented a notebook to facilitate the measurement of various aspects observed in the quality of the student projects. These include (a) concept, (b) design quality, (c) functionality, (d) transformability and spatial qualities of the design, (e) visualization strategies (XR), and (f) interaction and collaboration during the design process with XR (see Table 1). This approach allowed for a comprehensive assessment of the final design product using the UX+XR methodology. This evaluation process benefited the professors and the students, encouraging self-assessment and peer assessment, thus promoting a collaborative work approach among the students.

A rubric was applied in which the project's functionality and creativity were measured and evaluated through the distinct stages of the UX process: research, design, prototyping, testing, and feedback. The rubric focused on how each phase responded to the UX, ensuring the development focused on usability, interaction, and end-user satisfaction at each design stage. The rubric criteria for assessing the final design included concept, design quality, functionality, transformability and spatial qualities of the design, visualization strategies (XR), and interaction and collaboration during the design process with XR.

Table 1. Management and systematization of notebooks.

Observed Traits	Evaluation Type	Achievement Level Scale (%)				
		Very Deficient	Deficient	Sufficient	Excellent	Outstanding
(a) Concept Creative characteristics, innovation	SA PA	0 1	0 1	1 1	9 9	10 8
(b) Design Quality Coherence between concept, narrative, and final design product	SA PA	0 0	0 0	0 1	2 4	18 15
(c) Functionality It is usable, adaptable, and responds to the public and the market's needs	SA PA	0 1	0 0	0 1	3 2	17 16
(d) Transformability and Spatial Qualities of the Design Applied technology in design/structural design/spatial relationships	SA PA	0 0	0 0	0 3	5 5	15 12
(e) Visualization Strategies (XR)	SA PA	0 0	0 0	0 0	3 5	17 15
(f) Interaction and Collaboration during the Design Process with XR	SA PA	0 0	0 0	1 1	2 4	17 15

Notes: The Evaluation Type values were SA = self-assessment, PA = peer assessment; the Achievement Level Scale value ranges are Very Deficient = 19–0, Deficient = 39–20, Sufficient = 59–40, Excellent = 79–60, and Outstanding = 100–80.

4. Results

4.1. Analysis of Project Results and Design Process with UX and XR by Observed Traits

Data indicated that self-assessment and peer assessment primarily categorized the creative and innovation aspects as Excellent (9) and Outstanding (10). They were notable for the consistency between their creative traits and the innovation in their concepts. The results strongly emphasized originality, aligning self-assessment and external evaluators' perceptions. They suggest a solid understanding of user-centered design and an ability to communicate the concept effectively through architectural design.

Design quality (coherence between concept, narrative, and final product) exceeded expectations. The collected data shows that the Outstanding level predominated in self-assessment (18) and peer assessment (15). The score evidenced exceptional execution in integrating the concept with the narrative. This elevated level of achievement indicated a practical ability to conduct design from initial conception to final implementation, maintaining coherence and quality throughout all process stages.

Regarding functionality, including usability and adaptation to public and market needs, the students rated self-assessment as Outstanding (17), like peer assessment, which also received Outstanding ratings (16).

This demonstrates a strong understanding of user needs and an effective ability to design practical architectural solutions adaptable to different contexts and users.

The transformability and spatial qualities of the design were another criterion for which the data exceeded expectations. In this aspect, self-assessment was mostly Outstanding (15), and peer assessment was Outstanding (12). The design's transformability and spatial qualities consistently received great evaluations, indicating careful attention to flexibility and adaptability in the built environment. These results suggest an effective response to the changing demands of users and the environment. The students were attentive to developing structural systems based on digital technologies and automation to achieve architectural transformability according to user needs, especially regarding accessibility.

The implemented XR visualization strategies were successfully applied to the students during the design process and displayed in their project presentations. The data showed that self-assessment was predominantly Outstanding (17) in the visualization trait, and peer assessment was also predominantly Outstanding (15). Advanced XR visualization strategies determined a positive perception of the project's interior and exterior space, highlighting the ability to communicate and present architectural design effectively and persuasively through innovative technologies.

Interacting and collaborating during the design process, facilitated by XR technology, was a key strategy for developing the design and gathering feedback from potential users and external reviewers. The designer and reviewers synchronized and remotely evaluated the project in one virtual space. Each actor was represented as an avatar in the virtual model, and the participants could talk, send messages, and make marks and suggestions in the review. Most students selected Outstanding (17) in self-assessment, and peer assessment was predominantly Outstanding (15) in this category. Elevated interaction and collaboration scores during the UX+XR design process indicated effective collaboration and strategic use of advanced technological tools to enhance design communication and iteration, thereby strengthening project quality and efficiency.

4.1.1. Emerging Categories Analysis

The final evaluation focused on the effectiveness of the UX+XR methodology as a strategy for transformable architecture design in the classroom. We interviewed students who participated in the studio to assess the quality and understanding of this methodology. The student interviews indicated that the UX+XR methodology enhances creative work and transformable architecture during the learning process, as implemented by professors. The interviews also identified limitations and areas for improvement to consider for future applications.

Systematizing the data allowed us to categorize the main criteria for the usefulness of the UX+XR methodology in transformable architecture design. These categories are considered fundamental criteria from both academic and practical study perspectives, addressing critical elements that structure research references for organizing information (Table 2).

Emerging categories were relevant in each stage of the UX+XR methodology for transformable architecture projects, focusing on problem definition, characterization, and stage-specific targeting. We observed the proposal's effectiveness, concepts, design quality, functionality, transformability, spatial qualities, visualization strategies (XR), interaction, and collaboration during the design process with UX+XR.

Table 2. Emerging categories in UX-XR stages.

Teaching-Learning Environment	Process Emerging Categories			
	P1 UX: Empathizing and Researching XR: Conceptualizing	P2 UX: Designing XR: Visualizing	P3 UX: Prototyping XR: Creating	P4 UX: Testing XR: Collaboration
Architecture XR Assisted: Transformable and Interactive Design	Grounding the problem. Understanding the users.	Precedents analysis. Developing: concept, narrative, and detailed design product.	Create the design: functionality, transformability, and spatial qualities of the design. Technology: visualization strategies (XR). Build design and tectonic scale models digitally in medium- and elevated-fidelity museum quality.	Effectiveness of design proposal: usability, coherence. Models' interaction and collaboration during the design process with XR. Multi-user virtual environments for collaborative design. Final presentation.

The versatility of the UX+XR methodology in academic contexts arose because it provides a structured framework that fosters creativity and effective problem-solving relevant to distinct creative areas, like industrial design, engineering, graphic design, digital design, and the arts. This approach offers valuable insights into successfully implementing a method for transformable architecture design while integrating a foundation to create a teaching-learning strategy in education.

4.1.2. Analysis of Interviews

Within the study framework, interviews were conducted with students to assess the applicability of UX+XR methodology in transformable architecture design. We organized questions around the distinct stages of the design process. This approach provided a comprehensive view of how students perceive and apply UX+XR methodology in their projects and the associated challenges and benefits. The open-ended questions posed to the students, divided by stages, are presented in Table 3.

Considering Table 3, the analysis of student interviews revealed a positive perception and significant support for the UX+XR methodology applied in transformable architecture design. Below, we present an analysis derived from responses to open-ended questions structured across the stages of the UX+XR project.

In phase 1 (P1), the interest in UX+XR showed that 75% of students were highly interested in its applicability. They described the methodology as an attractive and powerful tool that allowed for deeper understanding and implementation in their transformable architecture projects. In terms of understanding the problem based on the user needs, 75% of students comprehended the problem better by applying empathy strategies, highlighting the importance of empathizing with users. This initial understanding facilitated a user-centered approach throughout the design process.

Table 3. Open-ended questions for students regarding the applicability of UX+XR in transformable architecture design.

UX+XR Phases	Open-Ended Questions
P1. UX: Empathizing and Researching XR: Conceptualizing	1. How would you describe your interest in the applicability of UX+XR in transformable architecture projects? 2. How did you understand the problem from the empathy (definition) stage?
P2. UX: Designing XR: Visualizing	3. How did applying UX+XR in transformable architecture facilitate your understanding of the subject? 4. How did you research and analyze the needs and expectations of users in your project?
P3. UX: Prototyping XR: Creating	5. How did UX+XR support and guide you in designing solutions for the transformable architecture project? 6. Do you feel confident, with the experience gained in the course, of applying UX+XR to design solutions for transformable architecture? Why?
P4. UX: Testing XR: Collaboration	7. Do you consider that UX+XR provided a systematic pathway for your project? How does this method help you in design decision-making? 8. How did you integrate innovative ideas and user feedback in the prototyping process to create solutions? 9. Do you consider that UX+XR provided better solutions than traditional methodologies? Why? 10. How did you manage user feedback during the testing phase of UX+XR to improve and refine the prototype, ensuring that the final solution was intuitive, useful, and satisfactory for users?
About the experience	11. Do you believe UX+XR will improve your academic performance in future subjects? 12. What were the main challenges you faced when applying the UX+XR methodology, and how did you overcome them during the project development?

In P2, centered on designing and visualizing, 82% of the students affirmed that applying UX+XR facilitated identifying and characterizing the subject to create a responsive design. They noted that this methodology allowed them to approach projects more efficiently and in a more structured way. In this matter, we discovered that it was necessary to perform more interviews to learn more about the involved users. When researching and analyzing user needs and expectations, 82% of students used UX+XR tools that helped them gain valuable insights, resulting in projects more aligned with user expectations.

UX+XR provided clear support and guidance in designing solutions for 75% of students in P3. They felt supported by a methodology that allowed them to explore diverse options and select the most suitable ones for their projects. Identifying what XR tool was most efficient per phase in the design process was a takeaway for efficiency in decision-making, idea communication, and visualization.

Most students on the course, 82%, feel confident about using UX and XR in their future projects. They highlighted how this methodology improved their ability to design effective, user-centered solutions and gave them a better understanding of spatial proportions and qualities.

During P4, a systematic pathway to develop models (tectonic and virtual) was defined. The data indicated that 75% of surveyed students believed that UX+XR methodologies provide a clear framework for project development. They appreciated the structured approach and well-defined stages guiding their design process. The methodology allowed 82% of students to integrate innovative ideas and user feedback into the prototyping process. This ongoing interaction ensured that the solutions were relevant and valuable.

When implementing XR for collaborative design and comparing it with traditional methodologies, 75% of students believed that UX+XR offered better solutions than traditional methodologies. Through testing by the project team, different users, and the design team, they highlighted greater problem-solving effectiveness and improved UX. During testing, 82% of students managed user feedback to improve and refine prototypes. This practice ensured that the final solutions were intuitive, useful, and satisfactory.

Using UX and XR, strategies enriched the student's academic performance during the transformable architecture design studio by facilitating design decisions, visualization, interaction, collaboration, and testing during the teaching-learning process. According to the interviews, 82% of students expressed confidence in the potential of the UX+XR methodology to impact their academic performance in upcoming courses positively. The experience gave them valuable skills to tackle complex projects through critical thinking, collaborative work, and the methodology's systematic stage-by-stage approach.

The assessments, conducted as part of the evaluations using the UX+XR methodology, consistently revealed a prominent agreement between self-assessments and peer assessments, particularly at the upper levels (Excellent and Outstanding). This suggests a shared positive perception among evaluators regarding the traits being evaluated.

At elevated performance levels, most assessed characteristics exhibited a significant concentration in the notably Excellent and Outstanding categories, displaying exceptional performance across all evaluated domains. Functionality and visualization strategies (XR) emerged as the primary strengths, consistently receiving elevated-level appraisals. This assessment has permitted a comprehensive performance overview across diverse traits, identifying strengths and areas for further enhancement.

4.1.3. Identified Challenges and How to Overcome Them

While the students faced challenges in applying UX+XR, 75% of students overcame them through adaptation and using the provided tools. The difficulties were related to hardware problems and intricacies in the transformability and structural design workflow. These challenges helped them to grow and improve their design and problem-solving skills. To resolve the hardware challenges, we suggest preparing accessible computers for future studios for the students in the same XR lab. Regarding transformability and structural design, the team must include civil engineering and structural design experts for the entire design process.

During the observation and notebook analysis, we noticed that 10% of the students had challenges using specific VR platforms that did not provide student licenses. In this sense, we opened access to them to remotely connect to the laboratory computers and equipment with floating licenses in the school. We will only select the VR platforms that offer direct access to future design studios.

The UX+XR methodology has proven to be a valuable tool for transformable architecture design, providing a structured and user-centered approach. Students recognize its effectiveness in all project stages and highlight its contribution to academic and professional development. UX+XR methodology reflects a positive experience and significant support for integrating UX+XR into the educational curriculum, with 75% to 82% of students favoring its use across various evaluated areas.

4.2. Transcendence of the Methodology: UX+XR+AI+Inmotics

During our research, we have identified specific stages in the architectural design process that require special attention. We have addressed the following: (a) understanding the design process without hindering creative capacity; (b) grasping the data and the problem or need that must be addressed; (c) conceptualizing feasible, innovative solutions; (d) translating the conceptual and experimental phases to architectural development; (e) manage constant uncertainty and make flexible, assertive decisions responding to changes from professors, clients, and socio-economic contexts; (f) communicating ideas effectively between the student and the professor or client; and (g) materialize the tectonic idea to navigate the constructive process.

Preparing future architects and designers is a challenge that forces us to reflect on how ready our students are to be professionally competitive in the architecture and construction field. A common misconception is that using innovative digital technology will automatically lead to more innovative design. However, the focus should be on creating innovative design ideas and lasting values in human and urban memories, using technology as a platform for development. Design quality depends not on technology but on the brilliant mind behind it. Using digital tools as real-time spatial translators significantly enhances the perception and comprehension of design elements and values.

4.3. Transformable Architecture Final Projects

The aspects of AI and inmotics were expressed in interface diagrams that reflected the operativity, interactivity, and transformability of the designed transformable architecture.

During the studio, the transformability aspect responded to the design problem. It was based on design elements, focusing on understanding the difference between skeleton and skin as transformable agents. The students selected the materials and mechanisms based on the principles of transformation. Utilizing XR, the students simulated the transformation of the architecture installation. Grounded on UX+XR, the participants successfully designed an interactive sphere for stress management and memory stimulation in older adults, an interactive portal for parks, a transformable housing for people without homes, a transformable bus station, an educational pavilion to be assembled by children, and an installation to nurse babies in public spaces (see Figure 3). In this studio, the design scale was small to develop the AI interface and to dedicate attention to the construction details, joints, and assembly processes for the transformability of the space.

The design products proved high spatial quality and an understanding of scale and user-adapted design. The students showed prominent motivation and responsibility with the design, considering their commitment to the users. Including XR scenarios is needed to understand the proportions of the space and simulated movement, use, and transformability (see Figure 4).

Figure 3. Project products from the XR Assisted studio 2023: (a) Milkweed bench; (b) Transformable housing; (c) The Sigh; (d) The path of the sun; (e) Educational pavilion; (f) Bus station.

Figure 4. Project transformation process: (a) The Sigh; (b) The path of the sun.

5. Discussion of Results

The following discussion addresses three critical points identified during the study: (a) the enrichment of learning using digital technologies, (b) the development of structured and empathetic design processes through integrating UX and XR, and (c) the enhancement of spatial and perceptual learning through immersive XR environments.

Regarding enrichment learning through digital technologies, integrating digital technologies such as XR and AI in architectural design significantly impacts students' learning experiences. Including XR sparked students' curiosity and increased their participation in autonomous learning. Using immersive digital tools, students explored design concepts in ways that traditional methods did not allow; for example, in the conceptual exploration using VR, the students were able to sketch directly in VR, change the scale and level of detail for the conceptual sketches and create walkthrough in real scale. In the design development stage, the students could circulate their design with VR on a real scale, overlap it in the real site with AR, and create multiuser collaborative virtual reviews using MR and VR. The ability to interact with these technologies enables students to push the boundaries of conventional design methods, resulting in innovative solutions. Moreover, the independent use of these tools gave students greater confidence and a sense of ownership over their learning process.

As for structured and empathetic design processes, integrating UX principles with XR technologies provided an organized, phased approach to design, actively involving users throughout all process stages. This approach ensured that the designs not only addressed technical needs but also human expectations, effectively meeting the actual demands of the users. By focusing on real-world problems, students developed a more profound empathy toward users, seeing them as human beings with diverse needs and desires rather than just clients (Aguirre-Villalobos et al., 2024). This user-centered design approach promoted critical thinking, allowing students to identify potential challenges early in the design process, such as accessibility issues or visual scale problems. This method's collaborative and iterative nature helped connect the gap between theory and practice, giving students a more comprehensive understanding of design challenges (Ferrer-Mavárez et al., 2020).

Finally, XR technology enhances students' understanding of essential design elements, spatial relationships, light management, and spatialized sound for spatial and perceptual learning. The immersive environments provided by VR allowed students to perceive these elements in a much more intuitive and impactful way than traditional methods like models or renders. The ability to visualize and experience design concepts within immersive environments represented a significant advancement in the design process. This immersive interaction improved students' spatial and aesthetic understanding and helped them communicate their ideas more effectively (Rauschnabel et al., 2022).

XR offers unique opportunities to enhance spatial perception by creating synthetic environments that generate sensory responses. Integrating UX strategies into the teaching-learning process enabled dynamic actions such as exploring virtual spaces, interacting with design elements, and experiencing emotional reactions, enriching the students' design capabilities and allowing them to communicate their ideas more effectively.

We demonstrated that integrating XR and UX principles improved the transformable architectural design process by enabling a deeper understanding of spatial and sensory elements through immersive digital environment simulations. XR facilitated real-time visualization and interaction, allowing designers to successfully explore innovative solutions and address users' needs. Additionally, the structured and empathetic approach facilitated by UX ensured that designs were user-centered and responsive to human experiences, improving the quality of design outcomes. In the context of learning, these technologies optimized the teaching-learning environment by directly engaging students in the design process, fostering critical thinking, and encouraging autonomous learning. UX+XR contributed to a more dynamic, user-centered, interactive, and innovative design process by bridging the gap between concepts and practical applications.

In terms of reflections and recommendations, it is imperative to (a) consolidate strengths by persisting in reinforcing aspects with exemplary performance, functionality, and visualization strategies; (b) improve areas with lower evaluations by undertaking a comprehensive analysis of segments receiving lower ratings to pinpoint potential enhancements; and (c) evaluate continuously to ensure progress, sustain an ongoing assessment process, and adapt design and collaboration strategies based on findings.

Exploring XR for transformable and interactive design revealed several promising areas that warrant future investigation. This exploration highlighted the need to improve XR environments' UX. It focused on three fundamental areas: how immersive the experience is, how interactive it is, and how well it adapts to user needs. Examining how these technologies can affect education and other areas is important. We should explore how different fields can collaborate on XR projects. In essence, a comprehensive examination of the societal impacts of XR technologies is imperative and will be considered in future research.

6. Conclusion

Examining and assessing how UX and XR were applied in this research led us to the following significant findings.

Applying the UX+XR with AI/inmotics method gave students a unique opportunity to engage in innovative multidisciplinary projects. It allowed them to gain firsthand experience in designing and developing XR experiences, enriching their learning and preparing them to tackle the challenges of the constantly evolving workplace.

The UX methodology helped include users in all stages of the design process, ensuring that the design product and XR experiences were designed based on their needs, preferences, and abilities. This resulted in more intuitive, functional, and satisfying final products for the users.

User participation in the design process improved the quality of the XR experience and promoted a sense of belonging and community among users. By being considered and heard, users felt valued and were more likely to adopt and enjoy the XR experience.

Lastly, concerning the value of inter-university collaboration and multidisciplinary teams, the collaboration between three universities and the involvement of different experts and multidisciplinary teams in the project provided a broad and enriching perspective. The partnership allowed for addressing challenges from different angles and focalizing the knowledge and skills of each team member, resulting in more comprehensive and practical solutions.

Combining UX, XR, inmotics, and AI to design transformable and interactive experiences significantly benefited students and users. It fostered inclusion, participation, and interdisciplinary collaboration to create high-quality and relevant XR experiences.

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Conflict of Interests

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ARTICLE

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Body of Mine, Yours, and Everyone in Between: Communicating Gender Dysphoria Through Immersive Storytelling

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Abstract

This article explores the potential of new, immersive realities to convey the complex experiences of gender dysphoria and body dissatisfaction, using the innovative and multi-award-winning experience *Body of Mine* as a case study. Recognizing a gap in understanding and empathy towards gender-queer communities, *Body of Mine* employs an innovative full-body tracking solution to place users into the body of someone else, combined with first-person documentary interviews and interactive elements aimed at fostering a deeper connection and insight into the transgender experience. Initial feedback from users indicates a heightened awareness and emotional connection to the challenges faced by individuals with gender dysphoria, as well as an increase in self-body positivity, based on a study conducted in collaboration with the University of Tübingen's Department of Psychology. This project underscores the power of immersive storytelling in fostering embodied understanding, while also acknowledging the ethical complexities and voyeuristic risks when sharing narratives from vulnerable communities, and explores innovative methods for tackling social issues through emerging technology. It concludes by contemplating the implications of immersive technologies for the concept of identity in a world that increasingly transcends the physical body, suggesting a future where the notion of self is not confined to physical form but is fluid, multifaceted, and continually redefined within boundless digital horizons.

Keywords

embodiment; gender dysphoria; identity; immersive; interactive media; LGBTQ+; storytelling; technology; transgender; virtual reality

1. Introduction

In the rapidly evolving landscape of media and communication, immersive technologies such as virtual reality (VR) have emerged not only as tools for entertainment but as potent mediums for empathy and understanding. These technologies, offering an unprecedented ability to "step into someone else's shoes," have ignited discussions around their potential to act as "empathy machines" (Milk, 2015). This term, both celebrated and contested within academic and development circles, suggests a capacity for immersive media to foster a profound connection to the lives and experiences of others, particularly those from marginalized or underrepresented communities (Bollmer, 2017; Bujić et al., 2020; Sora-Domenjó, 2022).

Fostering empathy and understanding towards transgender and gender diverse (TGD) individuals is particularly relevant in today's sociopolitical climate. There has been a significant rise in anti-trans legislation and policies across various regions, aiming to restrict the freedoms of TGD individuals. 2023 saw a record-breaking number of anti-trans bills introduced in the United States, prompting the Human Rights Campaign to declare a first-in-its-history "National State of Emergency for LGBTQ+ Americans" (Human Rights Campaign Foundation, 2024). The severity of these challenges underscores the urgent need for tools and methods that can promote greater understanding, empathy, and solidarity with the TGD community.

This article presents a case study on the VR experience *Body of Mine*, designed to convey complex narratives about gender dysphoria and body dissatisfaction. As both the creator of *Body of Mine* and the author of this article, I bring a unique perspective to this research. My dual role allows for an in-depth exploration of the design, development, and impact of the VR experience, offering insights from both a practical and theoretical standpoint. Recognized with several prestigious awards, including the Producers Guild of America Innovation Award, the SXSW Special Jury Award, and Best XR at Games for Change, *Body of Mine* demonstrates the power of VR to not only tell stories but also to profoundly change the way we connect with and understand our fellow human beings.

Employing a case study approach, this article will explore how *Body of Mine* not only utilizes novel techniques to foster an embodied understanding of intimate experiences but also addresses the intricate ethical challenges inherent in portraying these narratives. This exploration of *Body of Mine* is framed within a comprehensive research context that examines both the technological innovations and narrative strategies used in immersive VR experiences. Drawing on a wide array of references that include seminal works on the psychological impacts of VR, this article positions *Body of Mine* within the ongoing academic discourse concerning VR's capability to authentically replicate human experiences.

2. Background

2.1. Terminology

In this article, we employ specific terminology to ensure clarity and inclusivity when discussing gender and identity, consistent with both academic literature and community usage. The term "transgender and gender diverse" (TGD) is used to encompass transgender (trans) men and women, as well as non-binary individuals, intersex individuals, and those who identify as gender non-conforming. "Queer" is used as an umbrella term that includes not only the TGD community but also individuals who identify as gay, lesbian, bisexual, and asexual. These broad definitions aim to include the diverse experiences and identities within these communities, thereby ensuring comprehensive representation and fostering a more inclusive understanding of gender and sexual orientation.

2.2. Understanding Dysphoria

Body of Mine aims to promote a deeper understanding of gender dysphoria, a condition experienced by many TGD individuals. Gender dysphoria is characterized by a profound discomfort or distress caused by a discrepancy between a person's gender identity and their sex assigned at birth (American Psychiatric Association, 2013). Research into the etiology of gender dysphoria suggests both biological and environmental factors play roles. Neurobiological studies indicate that certain brain structures in TGD individuals are more similar to those typical of their experienced gender than their assigned one (Bao & Swaab, 2011). Socially, gender dysphoria involves complex interactions between the individual and their surrounding environment, including personal relationships, social interactions, and professional life, often leading to a pervasive impact on mental health and well-being (Meyer, 2003).

From a clinical perspective, gender dysphoria is associated with high levels of psychiatric distress, partly due to societal stigma and discrimination (Jackman et al., 2018). Studies show that individuals with gender dysphoria are at a higher risk for depression, anxiety, and suicide than the general population (Bockting et al., 2013). These risks are exacerbated by factors such as lack of social support, direct victimization, and discrimination (Hendricks & Testa, 2012). Therapeutic approaches for managing gender dysphoria typically include gender-affirming interventions such as hormonal treatments and surgeries, as well as psychological support to address associated mental health issues. Importantly, not all individuals with gender dysphoria seek medical transition; some find comfort in social transition or other forms of gender expression that affirm their gender identity. Similarly, not everyone who transitions experiences dysphoria; some may transition to achieve greater gender euphoria, which is the profound joy that comes from feeling aligned with one's gender identity (Beischel et al., 2021).

Recognizing the profound impact of gender dysphoria on mental health and well-being, it is crucial to explore innovative methods that can foster a deeper understanding of this condition. One promising avenue is the use of full-body VR applications which allow users to experience embodying an identity different from their own.

2.3. Gender Exploration Through Virtual Avatars

In gaming and virtual environments, avatars—digital representations of users, often portrayed as full-body humanlike characters—provide a transformative medium for gender exploration, particularly for TGD individuals, by offering a safe space for exploring different aspects of gender identity without the fear of immediate social repercussions (McKenna et al., 2022). This can help TGD individuals privately acknowledge their gender identity, an essential step before coming out in the real world (Whitehouse, 2022).

Gender-affirming avatars can provide both internal and external validation of gender identity and transition goals, which is especially vital for those not receiving affirmation in their real-world interactions. This validation can significantly impact TGD users in the real world by alleviating the effects of gender dysphoria, aiding in the consolidation of their identity and providing the confidence needed for the coming out process (Baldwin, 2018; Morgan et al., 2020). The ability to consistently present one's true self in virtual spaces can help stabilize and affirm their identity, making it easier to assert and maintain this identity in physical spaces over time (Marciano, 2014).

The interaction between players and their avatars goes beyond simple interaction, potentially forming social relationships where both entities contribute meaningfully. Traditionally viewed through a one-sided, non-dialectical lens, player–avatar relationships can exhibit fully social characteristics such as self-differentiation, emotional intimacy, and shared agency (Banks, 2015). When players embody avatars different from their own identity, such as men playing as female characters, these relationships can promote self-awareness and mutual influence, deepening the overall experience. These dynamics pave the way for more immersive engagements in VR, as further explored in the following sections.

2.4. Embodiment in VR

In VR, the concept of embodiment can be analyzed as a complex interplay between the senses of agency, self-location, and body ownership. These three components work synergistically to create an all-encompassing sense of embodiment that can deepen the level of immersion and emotional engagement in a VR experience (Kilteni et al., 2012).

The sense of agency refers to the feeling of control over actions within a virtual environment and the consequences of those actions. High levels of agency are critical because they affirm to the user that the avatar they control truly acts as their surrogate (Gallagher, 2012). A sense of agency can empower users to take control of their perspective-taking and learning processes, potentially making sensitive topics like gender identity feel less confrontational and more engaging (Ryan et al., 2006).

The sense of self-location involves the perceptual experience of the location of one's self within the environment. In VR, this is manipulated by aligning the visual perspective of the user with that of the avatar. Techniques such as adjusting the first-person perspective to match the avatar's eyes can significantly enhance this sense, making the user feel that they are physically inside the body of the avatar (Lenggenhager et al., 2007). *The Machine to Be Another* is an early example of leveraging the sense of self-location in VR to facilitate gender-swapping experiences by delivering real-time video from one user's head-mounted display to another (Bertrand et al., 2014).

Finally, the sense of body ownership refers to the sensory experience of identifying with and owning one's body. The sensation is typically achieved through multisensory integration, where visual, tactile, and proprioceptive cues are aligned (Kilteni et al., 2012). This integration can lead to proprioceptive drift, a phenomenon where external stimuli alter the perception of one's body parts and shift body ownership (Normand et al., 2011). Techniques such as the rubber hand illusion have shown how synchronous touching of a visible fake hand and an obscured real hand can lead to the sensation of the fake hand being part of one's body (Botvinick & Cohen, 1998). This principle can be extended to VR by synchronizing movements between the participant and an avatar, creating a compelling illusion of the avatar being part of the user's own body (Slater et al., 2009).

The integration of these elements into a cohesive sense of embodiment profoundly impacts users, amplifying emotions and enhancing the immersion of VR experiences. When users are fully embodied in an avatar, their emotional responses to virtual events can closely mirror their reactions to real-world events. This can be measured through physiological responses such as heart rate and skin conductance, which are more pronounced when users embody an avatar compared to observing an avatar from a third-person perspective (Armel & Ramachandran, 2003; Petkova et al., 2011).

2.4.1. The Proteus Effect

Neurocognitive research emphasizes the significance of the body in understanding others. Studies exploring the mirror neuron system reveal that observing someone else's bodily state activates similar brain regions to those engaged when experiencing that state ourselves (Keysers & Gazzola, 2009). This overlap in brain activity underscores a shared bodily representation between self and others, enhancing our first-person comprehension of other people's experiences. This effect, known as bodily resonance, plays a critical role in various social processes including the understanding of intentions, empathy, and the recognition of emotions (Slater et al., 2009).

The Proteus effect is a phenomenon observed in virtual environments where the characteristics of an avatar significantly influence the behavior and attitudes of the individual who embodies it (Yee & Bailenson, 2007). This effect, named after the Greek god who could change his form at will, underscores the profound influence that virtual embodiment can exert on real-world actions and mindsets. By manipulating avatar attributes such as appearance, race, or age, users often unconsciously align their behavior with the perceived traits of their avatars.

This phenomenon was first demonstrated by Yee and Bailenson (2007), who found that individuals assigned taller avatars acted more confidently in negotiation tasks, while those with more attractive avatars engaged more intimately in social interactions. In a separate study, it was shown that embodying an avatar that resembles Albert Einstein enhanced cognitive performance in problem-solving tasks, indicating the potential of VR to not only transform social attitudes but also to influence intellectual functioning (Banakou et al., 2018). This influence can tap into deeper aspects of identity and self-perception; for example, users embodying avatars of a different race showed reduced racial bias post-experience, while those embodying elderly avatars demonstrated increased empathy towards older adults and reduced age-related stereotyping post-experience (Peck et al., 2013; Yee & Bailenson, 2006).

One of the most promising applications of the Proteus effect is in therapeutic settings. Notably, it has been used to effectively promote healthier body image perceptions by allowing individuals to experience idealized versions of themselves, which can then influence their real-world self-image and behaviors (Fox & Bailenson, 2009). While this has shown considerable promise for individuals with eating disorders by temporarily correcting distorted body perceptions, further investigation is needed to explore how VR can specifically support mental health in TGD individuals by alleviating the symptoms of gender dysphoria (Matamala-Gomez et al., 2019).

2.5. Foundations of Immersive Journalism

The impact of embodiment in VR is magnified when combined with compelling storytelling and human-centric design (Gorini et al., 2011). Building on the ability to walk a mile in another's shoes, immersive journalism, a format pioneered by Nonny de la Peña, represents a revolutionary approach to storytelling, leveraging immersive technologies to place viewers directly into the news narrative (de la Peña et al., 2010). This method transforms the viewer from a passive observer into an active participant, offering a first-person perspective of events and stories.

One of the most powerful aspects of immersive journalism is its ability to convey complex social issues through experiential understanding. Viewers can, for example, experience the intensity of a refugee journey by stepping into the shoes of the people living these realities, the urgency of food insecurity and health vulnerabilities in the United States, or the realities of racism through the eyes of a Black man (Arora & Milk, 2015; Cogburn et al., 2018; de la Peña, 2012). Direct exposure to situations that otherwise feel distant can foster a deeper sense of urgency and a nuanced view of global and local issues, potentially leading to more informed and engaged public discourse (Immordino-Yang & Damasio, 2007).

The effectiveness of immersive journalism has been documented in various case studies. Schutte and Stilinović (2017) found that participants who experienced *Clouds Over Sidra* via VR reported increased perspective-taking and empathic concern post-experience compared to those who watched it in a 2D format. In another study, participants who were shown a VR experience chronicling the melting of glaciers had higher levels of environmental awareness post-experience than participants who engaged with traditional media (Thoma et al., 2023). Furthermore, a study on the experience *Becoming Homeless* indicates that the positive attitudes fostered by VR can be sustained over longer periods compared to traditional media; participants in this study who underwent the VR experience maintained positive attitudes towards the homeless over time, while those who engaged with traditional media saw their initial positive attitudes deteriorate over the eight weeks following the intervention (Asher et al., 2018; Herrera et al., 2018).

Immersive journalism, while revolutionary in fostering empathy through first-person perspectives, introduces complex ethical issues. Notably, there is the potential for false empathy, where users believe they fully grasp the subject's experience without appreciating its ongoing complexity; improper distance, which may prioritize engagement over the well-being of subjects and viewers; and identity tourism, where deeply personal narratives risk being objectified rather than genuinely understood (Bollmer, 2017; Raz, 2022; Silverstone, 2007). These concerns necessitate careful ethical considerations to ensure that the immersive experience remains respectful and authentic. These themes are further explored in Section 4.

Until now, immersive journalism has focused on placing users in a place or setting that is unfamiliar. *Body of Mine* takes this one step further by placing users into a body that is unfamiliar. Section 3 will analyze the development of *Body of Mine* from a technical and creative perspective, while examining its effectiveness, as well as potential risks, through anecdotal and empirical evidence.

3. *Body of Mine*—A Case Study

Body of Mine emerged from a deeply personal journey. After being outed as queer and subsequently estranged from my family, I began exploring how emerging technologies could provide safe spaces for queer understanding, connection, and healing, at a time when a safe space in the real world felt hard to find. I aimed to leverage the power of VR to create a sanctuary that not only allows queer individuals to explore their identities and connect with other stories from the queer community, but also to serve as a pivotal educational tool for a broader audience.

Body of Mine originated from a community-focused initiative, developed by myself and a team of queer and TGD creators from the University of Southern California and Arizona State University. This student project began as a collaborative effort aimed at leveraging collective experiences and technical skills to address the need for greater representation of queer stories in VR.

3.1. VR Experience Overview

Before entering VR, users are informed of the nature of the experience, and asked whether they have personally experienced gender dysphoria. This aims to be a more inclusive way of identifying cisgender and TGD audiences without forcing individuals to disclose their identity. Cisgender men are placed into the body of a woman, and women into the body of a man. Audiences who have previously experienced dysphoria are able to choose their avatar. This design aims to provide a euphoric experience for TGD audiences, allowing them to embody a gender-aligned avatar, while offering a profound perspective shift for cisgender participants. The avatar they embody is the only difference; otherwise, the experience, narrative, and audio remain the same.

Upon entering *Body of Mine*, users find themselves standing in front of a mirror, inhabiting their newly assigned body. Looking down, they see someone else's arms, legs, and torso moving in perfect synchronicity with their own movements (Figure 1). Touching different parts of this new, virtual body activates audio stories and interviews from TGD individuals, corresponding to that part of their body; touching their chest plays a story about top surgery, while touching their stomach reveals the story of a pregnant trans man.

Users begin the experience standing in the middle of a giant human chest cavity, surrounded by a massive beating heart, contracting lungs, and cavernous ribs that envelop them like a prison (Figure 2). As the experience progresses, this environment gradually transforms into a lush garden, with veins becoming vines,

Figure 1. A user looks down at their body in *Body of Mine*.

the lungs transforming into trees, and the heart morphing into a strawberry. Throughout this journey, users transition through the bodies of many diverse individuals. At the climactic moment, users transform into a glowing, genderless, amorphous spirit, symbolizing the pure essence of the human soul. This continuous transformation symbolizes the shared essence of our humanity, irrespective of the bodies we inhabit (Figure 3).

Figure 2. The environment of *Body of Mine*.

Figure 3. The transformation of *Body of Mine*.

3.2. Narrative Development

The development of *Body of Mine* was guided by several key goals. Our primary objective was to create an immersive experience that provides a deeper understanding of the complexities of gender dysphoria. Secondly, we aimed to promote a deeper sense of empathy for TGD individuals by enabling users to connect with the experiences of TGD people in an intimate and personal way. Our third objective was to highlight the diverse and unique stories within the TGD community, offering cisgender audiences a comprehensive perspective while allowing queer audiences to explore identity and connect with the stories of other queer individuals. These design considerations were central to each aspect of the project, ensuring that every element contributes to these overarching goals.

To ensure authenticity, extensive research and a diverse range of testimonials were collected before development commenced. We aimed to provide a holistic understanding of the nuanced dimensions of gender dysphoria by incorporating testimonials from a wide spectrum of voices, including transgender men and women, as well as non-binary, intersex, and gender non-conforming individuals. This diversity of voices creates a multifaceted view of gender dysphoria, rather than relying on a single narrator.

The narrative foundation of *Body of Mine* was laid through intimate audio interviews with primarily friends and peers. These interviews were conducted in a relaxed setting, using only a microphone. While each interview was specific to the individual, sample questions ranged from feelings associated with specific body parts—"what is your relationship with your chest?"—to more poetic, open-ended questions, designed to evoke a deeper, emotional truth—"what does being trans mean to you?" Narrative contributors were given the opportunity to review how their stories would be portrayed, ensuring their consent and comfort. Though all contributors were from the TGD community, they were not explicitly asked to self-identify in the experience. Their stories are not labeled nor assigned to specific avatars, aiming to represent the broader spectrum of gender dysphoria.

Each testimony was then analyzed and organized based on thematic content, emotional tone, and relevance to different parts of the virtual body interaction design. In order to foster a heightened sense of agency in the experience, each story was mapped to specific parts of the virtual body for the user to engage with. This tactile connection between self and other aims to deepen the user's understanding by engaging both the senses and emotions, fostering a more empathetic connection to the experiences shared.

The virtual environment itself serves as a poignant visual metaphor that was integral to the thematic core of the project. The design choice of a ribcage serves two purposes: first, to symbolize the universality of our human experience, regardless of gender; and second, to paint a visual metaphor of feeling trapped inside your own skin, a recurring sensation of dysphoria described by interviewees. Careful attention to detail, including high-resolution textures and precise shadow rendering, increased the environment's photorealism, thereby intensifying the immersive experience (Slater et al., 2009).

The second half of the experience delves into gender euphoria. The transformation of the ribcage into a garden symbolizes the profound process of growing into one's skin and embracing one's identity. This transition is enriched with carefully chosen responses from the interviews, while the user's digital body evolves through avatars of different sizes, colors, genders, and expressions, culminating in a warm, glowing silhouette representing the human soul. This sequence aims to conclude the experience with a powerful message of optimism, strength, and inspiration, encouraging users to see their personal transformations as beautiful and empowering, while celebrating the many bodies we inhabit.

The expected impact on users includes heightened awareness and empathy towards TGD struggles and a deeper understanding of gender identity complexities. The dissonance of seeing a body different from the users' own, combined with the documentary interviews, is anticipated to enhance emotional sensitivity and appreciation of the emotions tied to gender dysphoria. The poetics of the experience aim to evoke a profound emotional response and thoughtful contemplation, inspiring users to support and embrace diverse gender identities.

3.3. Technological Innovations

To achieve the deep level of immersion required by *Body of Mine*, cutting-edge VR technology and body-tracking systems are essential. This section explores the technological innovations that make this empathetic and immersive experience possible.

The project employs seven HTC Vive Trackers, strapped to the user's wrists, elbows, ankles, and pelvis, equipped with an Inverse Kinematics system in Unreal Engine to accurately replicate user movements onto a virtual human (Figure 4). This setup enables users to move naturally and see their movements reflected realistically in the avatar, strengthening the senses of self-location and body ownership. The Vive Pro Eye was selected as the head-mounted display for precise eye-tracking, translating subtle eye movements and blinking onto the eyes of the virtual human, while a Leap Motion hand-tracking device provides detailed finger tracking, further heightening the sense of body ownership.

Figure 4. Technical setup of *Body of Mine*.

The project leveraged the dissonance of proprioceptive drift to creatively address the limitations of at-home motion capture systems, which often suffer from calibration issues and slight inaccuracies. Instead of seeing these imperfections as drawbacks, the development team embraced them, using this dissonance as a metaphor for the disconnect between mind and body experienced by those with gender dysphoria. This approach not only acknowledged the limitations of current VR technology but turned them into a meaningful part of the narrative, enhancing the thematic depth and emotional realism of the experience.

The use of Unreal Engine's MetaHumans was a strategic choice, driven by their photorealistic capabilities and cost-effectiveness as a free resource. Despite inherent limitations in the MetaHuman Creator, such as predefined body types (short/medium/tall and underweight/normal weight/overweight) and binary gender options (male/female), the project team creatively expanded the representation of diverse gender expressions by customizing avatars with tattoos, surgery scars, and varied hairstyles that transcended traditional gender binaries. All MetaHumans were depicted in simple underwear, avoiding the distraction of more elaborate clothing. Lights and colliders were anchored to joints on the MetaHuman skeleton in order to precisely detect and respond to the user's touch (Figure 5).

Self-funded on a small budget, *Body of Mine* leveraged artificial intelligence to overcome financial and technical challenges. Large language models like ChatGPT generated code and assisted in programming, while diffusion models created artistic assets. This strategic use of AI broadened accessibility to VR creation, enabling authentic storytelling from marginalized communities who may not have large budgets or technical experience. It marks a shift towards democratizing technology, allowing independent creators to develop complex virtual experiences without extensive resources or years of technical experience. Sub-section 3.4 explores the anecdotal, empirical, and social impact of *Body of Mine*, showcasing the potential of democratized technology to resonate globally.

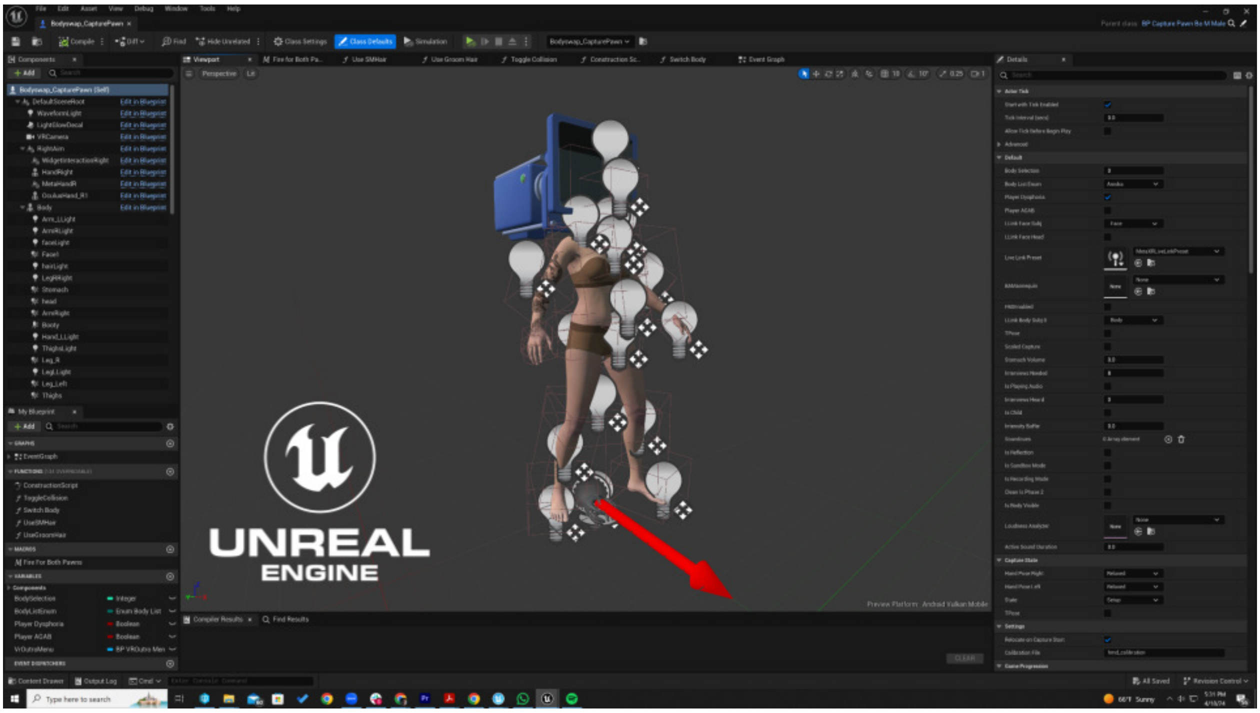

Figure 5. A MetaHuman setup in Unreal Engine.

3.4. Impact

Since its debut, *Body of Mine* has garnered acclaim at international film festivals and impacted audiences worldwide. The piece was celebrated with major awards such as the Producers Guild of America Innovation Award, the SXSW Special Jury Award, a BAFTA Student Award, Best XR at Games for Change, an International Premiere at the Venice International Film Festival, the Social Impact Award at FilmGate, Best VR at both the B3 and deadCenter film festivals, and more. Critics and media outlets recognized the significant impact of the VR experience, with WIRED noting that *Body of Mine* "broke through a psychological barrier few pieces of media ever have" (Ravenscraft, 2023).

The emotional resonance of *Body of Mine* was palpable in the reactions it elicited from viewers. Exhibited in regions like Texas, Oklahoma, and Florida, which face significant challenges regarding anti-trans legislation, the piece served as more than just an artistic expression—it became a catalyst for important conversations. In a viral video of a Pride screening in Oklahoma City, audiences both young and old, cisgender and TGD, are seen emotional while exiting *Body of Mine* (Kostopoulos, 2023). Many expressed that the experience provided them with a deeper understanding of gender dysphoria, with some finding a new comfort in their own identities.

The experience ignited profound personal revelations, enabling individuals to reconcile with aspects of themselves they had previously viewed negatively. One woman emerged with a newfound love for a scar she had long despised, seeing it in a new light after the VR experience. Another, who had spent her life wearing a burqa, discovered a renewed acceptance and appreciation for her body. These powerful transformations underscore the potential of VR to foster greater self-acceptance in ways traditional mediums often cannot.

3.4.1. Embodiment Study

Motivated by such profound reactions, we sought to delve deeper into the effects of the experience on body image perceptions. In collaboration with the University of Tübingen's Department of Psychology in Germany, we designed a study to quantitatively measure these effects using validated psychological instruments.

The study aimed to assess the impact of *Body of Mine* on participants' body image states. The primary objective was to determine if engagement with the VR experience could improve self-image. It was conducted at the B3 Moving Images festival in Frankfurt, Germany, where the experience was available to the general public at a free public art gallery. Each session lasted approximately 30 minutes, during which participants experienced the entire *Body of Mine* narrative from beginning to end. The study sample consisted of 36 English-speaking respondents, who participated voluntarily by opting in with informed consent. The data collection occurred over three days using a pre- and post-experience questionnaire. The demographic breakdown was diverse, with a mean age of $M = 35.9$ ($SD = 12.5$) ranging in age from 18 to 65, including 18 cisgender men, 14 cisgender women, two non-binary individuals, and one transgender man.

Participant recruitment involved individuals who were already intending to experience *Body of Mine* and consented to participate during sign-ups. Gender identification was recorded through an onboarding survey where participants self-identified using a combination of predefined options and free-text entries. Cisgender participants self-identified as such, with no assumptions made based on the absence of a TGD declaration.

The sample may not be fully representative of the general population due to the specific setting of an art gallery. Additionally, due to English being a second language for many participants, language barriers may have influenced responses and/or comprehension of the experience.

We utilized the short form of the body appreciation scale II (S-BAS-2) and the body image states scale (BISS), both featuring 5-point Likert scales. The S-BAS-2, an enhanced version of the original scale, assesses individuals' acceptance of, favorable opinions toward, and respect for their bodies (Tylka & Wood-Barcalow, 2015). This scale has demonstrated strong psychometric properties, including unidimensionality and reliability across different genders and samples. The BISS is specifically designed to measure transient body image states, making it particularly useful for assessing the short-term impacts of interventions (Cash et al., 2002). We performed analyses using R version 4.3.3, employing paired t-tests to compare our pre- and post-results. All analyses were two-sided, with the significance level set at $p < .050$.

Results revealed a statistically significant increase in body appreciation, as measured by the S-BAS-2, $t_{(33)} = -5.44$, $p < 0.001$, $d = -0.93$, from pre ($M = 3.83$, $SD = 0.55$) to post ($M = 4.25$, $SD = 0.53$; Figure 6a). Furthermore, body dissatisfaction, as measured by the BISS, significantly decreased, $t_{(33)} = -3.58$, $p < 0.001$, $d = -0.61$, from pre ($M = 4.72$, $SD = 0.57$) to post ($M = 4.18$, $SD = 0.91$; Figure 6b). For both body-related variables, the effect sizes were large, indicating substantial changes. The S-BAS-2 in this study had a good internal consistency with a Cronbach's alpha of greater than 0.85, while the BISS exhibited poor internal consistency with a Cronbach's alpha of less than 0.39. This suggests that while the results are promising, they should be interpreted with caution. Future research could focus on improving the reliability of the BISS or employing alternative instruments that may provide more consistent measures of body image states.

Regarding the understanding of gender dysphoria, significant improvements were observed. The agreement on a 7-point Likert scale for the item "how well do you understand the concept of gender dysphoria" increased from $M = 3.41$ ($SD = 1.65$) to $M = 4.79$ ($SD = 1.71$), $t_{(33)} = -6.08$, $p < 0.001$, $d = -1.04$. Additionally, agreement with the statement "I identify with the struggles of trans people" rose from $M = 4.61$ ($SD = 1.57$) to $M = 5.44$ ($SD = 1.39$), $t_{(33)} = -3.59$, $p < 0.001$, $d = -0.62$. Similarly, the item "people should be free to change their gender" showed a significant increase from $M = 6.02$ ($SD = 1.19$) to $M = 6.29$ ($SD = 1$), $t_{(33)} = -2.32$, $p = 0.027$, $d = -0.40$ (Figure 7a–c). These results suggest that *Body of Mine* fostered greater empathy and understanding

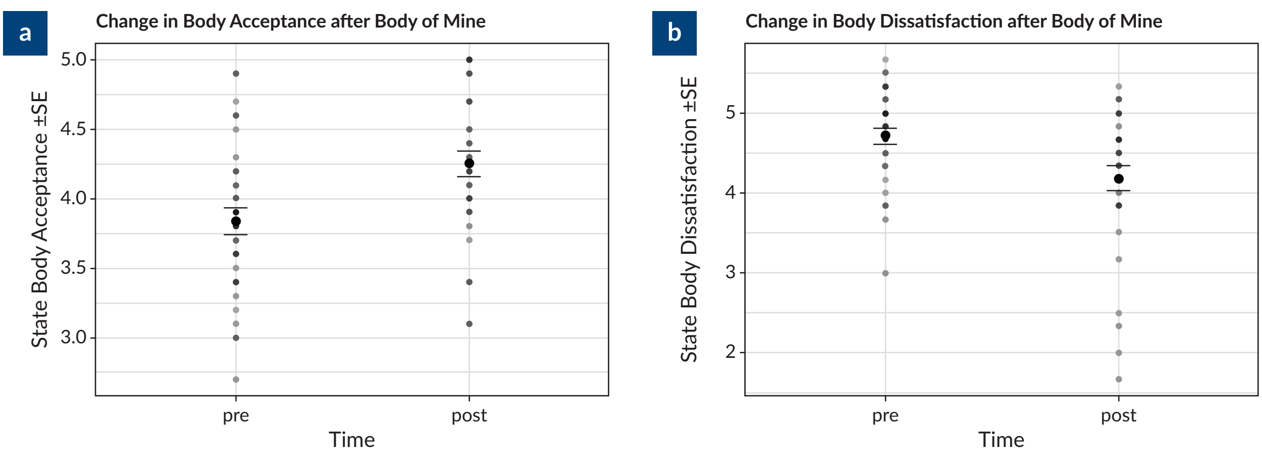

Figure 6. Results of S-BAS-2 (a) and BISS (b).

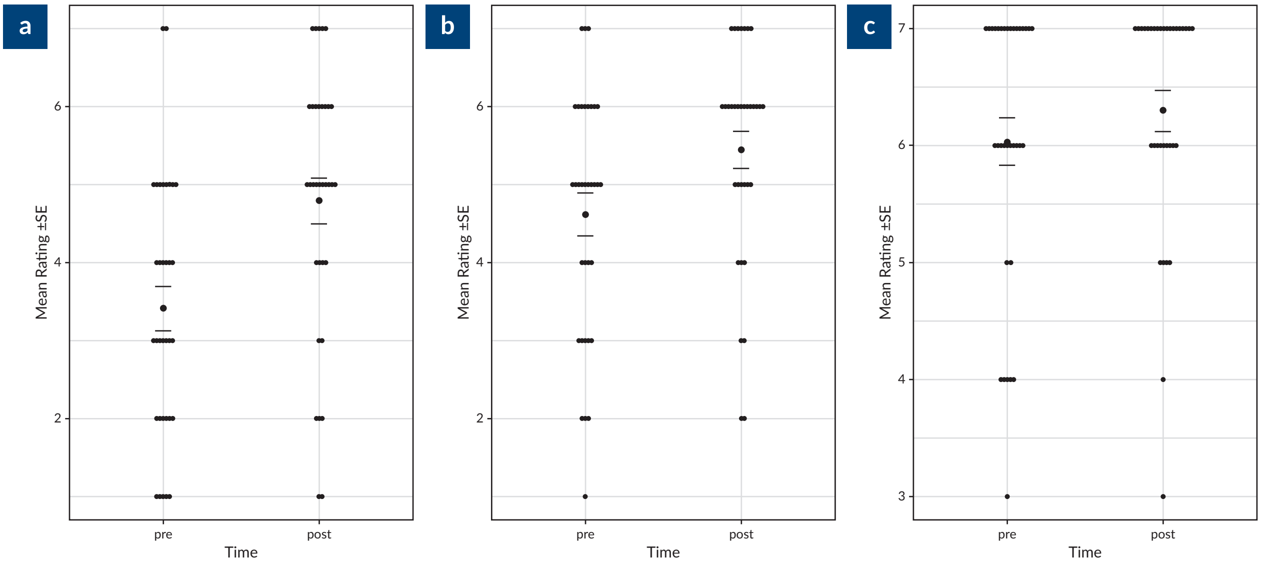

Figure 7. Results of *Body of Mine* on empathy and understanding using a 7-point scale for the items (a) how well do you understand the concept of gender dysphoria?, (b) I identify with the struggles of trans people, and (c) people should be free to change their gender.

toward the experiences of TGD individuals. The marked increase in identification with the struggles of TGD individuals is particularly noteworthy, indicating that participants not only gained an intellectual understanding of gender dysphoria but also connected it to their own bodily insecurities. This personal connection likely fostered a deeper, more profound sense of empathy, allowing participants to recognize and resonate with the struggles of others on a more intimate level.

Despite the limitations of the study, these preliminary findings are promising and support further investigation into the use of immersive technology to enhance body image perception. The reported improvements in body appreciation and reductions in body dissatisfaction highlight the potential of VR as a powerful tool for addressing body image issues across diverse groups. Future research could explore how experiences like *Body of Mine* can specifically aid individuals living with gender dysphoria, as well as investigate the long-term effects of experiences like *Body of Mine* on perceptions and attitudes towards TGD individuals.

3.4.2. Accessibility and Technological Adaptations

To improve accessibility and reduce the technological complexity of the original setup, a standalone version of *Body of Mine* was developed for the Meta Quest platform. This adaptation was released on the Meta Horizon Store in June 2024, available for Quest 3, Pro, and 2. This version eliminates the need for HTC Vive Trackers, broadening accessibility to a wider audience. The Quest adaptation utilizes the built-in capabilities of the headset for motion capture, providing a highly immersive experience without the need for extensive setup.

While the Quest version offers significant accessibility benefits, there are some tradeoffs. The lack of external trackers results in less accurate tracking, and optimization for mobile rendering means lower poly models, the absence of real-time shadows, and less detailed avatars. Additionally, face and eye tracking features are only available on the Quest Pro. However, these compromises are balanced by the benefit that a much broader audience can access the experience. Importantly, the power of the storytelling remains uncompromised in the Quest version. The narrative and emotional impact carry significant weight, ensuring that the experience continues to profoundly affect audiences.

The Quest version's ease of use makes it ideal for integration into schools, libraries, LGBTQ+ centers, and other community spaces, promoting broader dissemination and educational use. The original experience, which features more accurate tracking and greater realism, is available on Steam, and is recommended for deeper immersion and research applications. Our two-pronged approach, offering both the high-fidelity original version and the more accessible Quest version, exemplifies our commitment to balancing cutting-edge immersive technology with broad accessibility. This strategy underscores our dedication to ethical integrity and the democratization of immersive technology, ensuring that impactful storytelling is available to all. Section 4 will delve deeper into the ethical implications of immersive storytelling, exploring the challenges and responsibilities that accompany these innovative mediums.

4. Ethical Considerations

In traditional documentary filmmaking, ethical standards are well-established, focusing on the accuracy of the depiction, fairness in representation of the subjects' stories, and respect for the subjects' dignity (Bernard, 2011). However, VR introduces a new dimension to storytelling—simulation—that complicates these ethical considerations. Simulation in VR is not merely about replicating visual and auditory elements of a story, but about reconstructing the sensory and emotional landscape of an experience. While this can significantly enhance empathy and understanding, it also raises critical ethical issues about the authenticity of the experiences being simulated and the impact on viewers (Nash, 2018).

These challenges stem from the need to balance factual integrity with the immersive nature of the medium. Creators must navigate the thin line between enhancing understanding through sensory experiences and fabricating elements that could mislead viewers or misrepresent subjects. This is further complicated by the potential for VR to induce false empathy, where users feel they fully understand and empathize with a subject without recognizing the complexities or continuing struggles that cannot be fully captured in a simulation (Bollmer, 2017). This could lead to over-identification with the subjects, resulting in viewers feeling a personal connection or experience that is not truly theirs, potentially overshadowing the real voices and experiences of the subjects (Nash, 2018).

The risk of exploitation is additionally heightened in VR environments, necessitating careful attention to obtaining informed consent. Subjects may not fully comprehend how their stories and likenesses will be used, or the extent to which their experiences will be immersive and potentially exposed to a global audience. The intimacy and immediacy of these stories can inadvertently lead to voyeurism or "identity tourism," where viewers engage with deeply personal and sometimes distressing stories in a manner that objectifies the subjects rather than fostering genuine understanding or empathy (Raz, 2022).

Another significant concern is the risk of re-traumatization for both the subjects featured in the VR experience and viewers. Subjects, as well as individuals with similar experiences, might relive traumatic events more vividly than they would through traditional media, while viewers are exposed to these intense experiences in a more embodied way, which can lead to psychological impacts not typically associated with conventional documentary viewing. As a result, immersive experiences can struggle with maintaining the proper distance needed in ethical storytelling (Silverstone, 2007). Without this distance, there is a risk that the immersive experience could prioritize engagement over the well-being of its subjects and viewers.

While the challenges of VR as a medium for documentary work are significant, they should be viewed as opportunities to innovate ethically and responsibly. The inherent limitations of technology mean that an exact, comprehensive simulation of one's lifelong experience is impossible. VR environments can recreate specific scenarios and evoke sensory and emotional responses, but they cannot fully encompass the nuanced, multifaceted nature of an entire human life, with its myriad interactions, thoughts, and feelings experienced over the years. Recognizing these limitations can help creators avoid the pitfalls of over-simplification and misrepresentation, encouraging a more focused and thoughtful approach to storytelling.

Given these constraints, the pursuit of emotional truth becomes a more viable and meaningful objective. Emotional truth captures the essence of experiences in a way that resonates on a personal and profound level with viewers. By conveying the internal realities of subjects—how they feel and what their experiences mean to them—VR can avoid the ethical issues associated with striving for absolute, often unattainable, factual precision. A focus on emotional truth allows VR experiences to engage viewers deeply, creating a space where empathy and understanding can flourish beyond the limitations of traditional narration. It also ensures that stories remain authentic and respectful, as they are grounded in the genuine emotional experiences of the subjects rather than a superficial replication of events. A community-first approach throughout this process is paramount. By engaging directly with the community, the project becomes a collaborative effort that empowers the subjects, and ensures that the final product resonates truthfully with both viewers and those represented.

In *Body of Mine*, emotional truth is communicated through innovative narrative techniques, visual metaphors, and sensory illusions that resonate with the viewer's personal experiences. The transformation of the ribcage into a garden, for example, symbolizes personal growth and self-love. Proprioceptive drift, combined with the imperfections of motion capture, allows viewers to feel a sense of dissonance between their perceived physical self and the virtual representation, enhancing the story's emotional depth. These techniques do not aim to replicate reality but to capture the deeper emotional truths of the subjects' stories. By directly involving the TGD community and prioritizing consent and privacy, the project ensures authenticity and empowers subjects, making the final product resonate truthfully with both viewers and those represented.

As immersive storytelling continues to evolve, it is crucial to recognize that this medium should not be constrained by moral ultimatums, but should instead allow ethical considerations to guide creative and responsible storytelling. Ethical guidelines in VR should encourage exploration and innovation while ensuring that the narratives are crafted with sensitivity and integrity. This evolving journey promises not only to enhance our understanding of complex human experiences but also to expand the horizons of storytelling itself, inviting us all to imagine and participate in shaping the future of immersive media.

5. Implications on Identity

As immersive technologies continue to develop, our understanding of identity is poised for a dramatic shift. Identity, which is traditionally rooted in physical and biological characteristics such as gender, race, and physical appearance, may increasingly be seen as fluid, modular, and multifaceted, shaped not just by physical attributes but also by our digital representations and experiences (Giddens, 1991).

Digital worlds such as VRChat, and platforms incorporating identity swap features like Snapchat's gender swap filter, serve as early examples of how digital environments are enabling modular and fluid expressions of identity. In VRChat, users can adopt any form, ranging from realistic human avatars to fantastical creatures, thereby exploring diverse identities in safe, controlled environments. This modularity allows individuals to experiment with aspects of their identity in ways that can be both empowering and transformative. While augmented reality filters, such as Snapchat's gender swap filter, currently exist solely through smartphones, it is not difficult to imagine a near future where these filters are seen through wearable devices, challenging the importance of physical over digital representation in the real world.

The ethical implications of these technologies are profound. As we embrace digital identities, issues of consent, privacy, and authenticity become increasingly complex. The creation and manipulation of digital selves also raise questions about the ownership of digital identities and the potential for misuse or harm. Furthermore, there is a risk of deepening the digital divide, where access to advanced technologies is uneven, potentially exacerbating social inequalities.

Alongside these ethical challenges, however, lies a profound potential for not only the liberation of identity beyond physical constraints, but also significant improvements in mental health (Matamala-Gomez et al., 2019). This capability can be particularly transformative for those experiencing gender dysphoria or body dissatisfaction, providing relief and a sense of alignment that might be otherwise unattainable due to the high costs or inaccessibility of transitioning (Whitehouse, 2022). Such technological interventions can serve as vital therapeutic options, offering psychological comfort and support where traditional medical treatments may fall short, and freeing individuals to present themselves in ways that align with their internal sense of identity, unbound by physical or biological constraints.

As immersive technologies continue to evolve, they promise a future where the self is liberated from traditional constraints and free to explore new realms of possibility. Navigating this future requires us to balance the vast potential of these technologies with the significant ethical challenges they present, ensuring their use promotes inclusivity, understanding, and respect for all facets of human identity.

6. Conclusion

The exploration in *Body of Mine* demonstrates the profound impact of immersive storytelling on enhancing empathy and deepening the understanding of complex social issues such as gender dysphoria. While the potential of immersive technologies to reshape our perceptions of identity and enhance human connection is substantial, it also brings forward critical ethical considerations. The risks of voyeurism, exploitation, and the potential for re-traumatization must be navigated with rigorous ethical standards to prevent misuse. A steadfast commitment to emotional realism is essential to overcoming these limitations.

As virtual and augmented realities continue to advance, the concept of a fixed, physical body may become more abstract, with digital avatars and virtual experiences allowing individuals to explore and express their identities in innovative ways. This evolution could profoundly affect how we perceive ourselves and interact with others, necessitating a redefinition of identity beyond traditional boundaries. Charting the future of immersive technologies responsibly will define the contours of empathy and identity in our increasingly digital world.

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Conflict of Interests

The author declares no conflict of interests.

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About the Author

Cameron Kostopoulos is an award-winning immersive creator. Their debut experience *Body of Mine* was the recipient of the PGA Innovation Award, and won prizes at SXSW, BAFTA, Games for Change, and more. They are the founder & CEO of Kost, a storytelling collective aimed at helping us better understand ourselves, the world around us, and our fellow human beings. They hold a BFA from the prestigious USC School of Cinematic Arts and an MA from ASU's Narrative & Emerging Media Program.

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How Different Training Types and Computer Anxiety Influence Performance and Experiences in Virtual Reality

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Abstract

Virtual reality (VR) can place people in unique environments and facilitate engagement, making it a compelling tool for storytelling and learning. However, experiencing narratives requires immersion, which can be difficult for those who are anxious about technology. Prior research has shown that training new users on how to use VR before they engage in learning tasks housed in VR is critical. The right kind of training and targeted guidance may help people, including those with computer anxiety, better navigate virtual experiences. However, best practices for how training should be administered remain unclear. This study examined how training type (paper, video, and VR) and computer anxiety influenced outcomes using a large sample size ($n = 284$). We measured performance and self-reported outcomes while participants navigated computer-graphic scenes, manipulated three-dimensional objects, and watched a narrative 360° video. Results showed that participants who received training via video or VR mastered more VR functions than those who received training via paper. Additionally, those who trained directly in VR had less of a negative experience using VR for completing tasks. Furthermore, participants who trained in VR perceived the training as more useful and found the VR tasks to be easier compared to those who received training in paper or video. Finally, those with high levels of computer anxiety, regardless of training, had more negative outcomes than those with low computer anxiety, including having less mastery of VR functions and engagement with the 360° video content, perceiving the training as being less useful, completing tasks with more difficulty, and having more of a negative experience. Our results suggest that keeping the medium the same both during training and doing is ideal. We discuss implications for theories of information processing in VR, as well as implications for scaled engagement with narratives and learning in VR.

Keywords

narrative; recall; storytelling; training; virtual reality

1. Introduction

Virtual reality (VR) is a powerful medium that can transport and immerse users into stories within virtual environments. As a result, VR has the ability to place scenes or experiences directly into the minds of users, making it a strong tool for storytelling, journalism, and education, where the feeling of "being there" may play a pivotal role. For instance, in journalism, research has shown that those who experience stories in VR feel more presence, interaction, and perceived source credibility than those who experience stories through text and pictures (Sundar et al., 2017). Similarly, in education, research has shown that those who learn in VR experience more presence, enjoyment, motivation, and learning transfer than those who learn through low-immersion media (Makransky, Borre-Gude, & Mayer, 2019; Meyer et al., 2019; Petersen et al., 2020).

However, VR has also been described as a double-edged sword: While VR may elicit higher arousal and presence, it has also shown to be particularly challenging with narratives, with the medium causing decreased focused attention, recognition, and recall (Ahn et al., 2022; Barreda-Ángeles et al., 2020). VR experiences are often multisensory, meaning viewers are exposed to visual, auditory, and haptic feedback at once. As a result, the cognitive resources required to process presented material may exceed cognitive capacity (Mayer & Pilegard, 2005). The features that make VR attractive, such as interactivity and presence, may reduce their effectiveness by overwhelming users who have to adapt to the technology and leading users to engage in extraneous processing that does not support the intended goal of the material (Mayer et al., 2022). Furthermore, VR has been shown to have a slow learning curve: Providing ample time and training to adjust to the medium is critical prior to expecting users to engage with the presented material (Han et al., 2022).

In this vein, to realize the full potential of the technology, allowing users to familiarize themselves with the medium through training is a critical step (Han & Bailenson, 2024). However, training can come in different forms, such as paper-, video-, and in-person-based instruction, each of which may yield different outcomes for different people. This current study investigates three forms of training prior to using VR to complete various tasks and watch a 360° video, to see how individual differences in computer anxiety influence outcomes.

2. Background and Previous Work

2.1. Processing Information in Immersive VR

The cognitive theory of multimedia learning posits that the type of processing that users engage in while learning in immersive VR leads to different outcomes (Mayer & Pilegard, 2005). Similarly, in storytelling, if a viewer experiences cognitive overload, there may be undesirable consequences, such as negative feelings of frustration and confusion (Feng, 2018). Such consequences are a result of extraneous processing, which occurs when there is distracting or irrelevant information. This is a particular concern for VR because it has a higher level of extraneous content compared to other media such as video (Makransky, Terkildsen, & Mayer, 2019; Moreno & Mayer, 2002). VR users may spend more time exploring the environment around them, which may divert their attention away from events that are central to the main narrative—a conflict described as the "narrative paradox" (Aylett, 2000; Barreda-Ángeles et al., 2020). The multisensory nature of VR or the high spatial presence that the medium provides has been shown to lead to users having to process simultaneous streams of information and affect how information is processed (Ahn et al., 2022; de Barros & Lindeman, 2013).

Furthermore, people who are unfamiliar with the technology or those with computer anxiety may have more difficulty learning due to the novelty of figuring out how to use the medium and interact with the environment (Makransky, Terkildsen, & Mayer, 2019; Wu et al., 2020). Additionally, those with computer anxiety tend to have more negative technological experiences (Torkzadeh et al., 2006). A study by Ahn et al. (2022) investigated the role of computer anxiety in users' ability to engage with a narrative about the consequences of ocean acidification either in VR or a video. They found that individuals with high computer anxiety experienced greater spatial presence regardless of media, compared to those with low computer anxiety. Results suggested that those with more computer anxiety have to allocate more processing resources to engage in spatial presence in the media, whereas those with lower computer anxiety were able to allocate fewer processing resources to spatial presence, leaving more resources to process information. Accordingly, those with high spatial presence led to lower recall of the mediated information.

Research has also found that time spent with media and experience can influence both self-reported and nonverbal outcomes (Bailenson & Yee, 2006). For example, Han et al. (2023) investigated how people's experiences may change as they grow more comfortable using VR. The results suggest that, over time, as people grow accustomed to VR, they may be able to focus more on being present and paying attention to their surroundings, and less on learning how to navigate the environment and the medium. Other longitudinal studies have shown similar results, suggesting that without learning how to use VR first, people cannot fully process what they experience in VR (e.g., Han et al., 2022).

2.2. The Role of Training Prior to the Use of Technology

The process of training can enable individuals to gain attention, set expectations, and enhance learning via symbolic coding (Mesmer-Magnus & Viswesvaran, 2010). Specifically for training prior to using technology, training can improve perceived self-efficacy, reduce unnecessary cognitive load, and impact confidence (Jung et al., 2019; Saville & Foster, 2021; Torkzadeh & Van Dyke, 2002).

However, training has shown to vary in effectiveness, as it can be impacted by individual differences, method, and content (Arthur et al., 2003; Cannon-Bowers et al., 1998). Given this, there has been limited research focusing on the different modalities of training, such as static paper-based training and animated video-based training (Höffler & Leutner, 2007). Paper-based training has been argued as having increased accessibility, allowing individuals to control their pace and engage in active processing. Meanwhile, with video-based training, both auditory and visual information can be presented to strengthen each other. Video training can additionally provide an easy-to-follow model for the individual to be able to learn and mimic the observed actions (van der Meij & van der Meij, 2014).

Past research examining VR training has shown that it helps the user experience to train people before they enter VR to reduce the novelty effect and help them navigate the environment (Miguel-Alonso et al., 2023). Training prior to VR use has improved satisfaction during learning, lowered cognitive load when presented with novel concepts, and increased retention and transfer (Meyer et al., 2019; Miguel-Alonso et al., 2023). Meanwhile, those without training were more overwhelmed with sensory information, likely because they did not have resources to effectively select, organize, and integrate information into long-term memory (Meyer et al., 2019). Finally, another study by Liu et al. (2021) showed that providing preparatory information to read prior to an embodied immersive VR program promoted transfer of skills.

Similarly, training interventions, which are activities that are performed prior to the task that counteract specific negative aspects, have shown to be successful. For example, providing attentional advice successfully reduced distraction and increased learning during a VR program (Howard & Lee, 2019). However, computer anxiety has been shown to reduce the effectiveness of training. A study by Torkzadeh et al. (2006) examined the relationship between training and computer self-efficacy, and how this was influenced by computer anxiety. Students part of a course learned about computers and interacted with them. Results showed that, while training significantly improved computer self-efficacy, those with low computer anxiety improved their self-efficacy significantly more than those with high computer anxiety (Torkzadeh et al., 2006).

2.3. Context-Dependent Memory and Narrative Engagement

One way to display engagement with a narrative is to examine what users remember following the experience. Prior literature on context-dependent memory shows that people's memory retrieval is better when they are in the same context in which the memory was encoded. According to the encoding specificity principle, a retrieval cue will be effective in prompting recognition if it was encoded with the relevant item during learning (Tulving & Thomson, 1973). For example, in an iconic study by Godden and Baddeley (1975), divers learned passages of prose either on land or underwater, and were then asked to recall the words in the same or different environment. Participants recalled more words when they were tested in the same environment in which they learned them.

Since those early studies, several distinctions have been made related to the context, such as the intrinsic and extrinsic context, which distinguishes the semantic aspects of the stimulus that are processed when it is perceived (i.e., intrinsic context) from characteristics of a situation that are irrelevant to the processing of the stimulus itself (i.e., extrinsic context), with the latter having less of an influence on memory retention (Hewitt, 1977, as cited in Godden & Baddeley, 1980). Similarly, Baddeley (1982) argues that cues during encoding and retrieval can either interact meaningfully (i.e., interactive context) or have no meaningful interaction (i.e., independent context). This research points towards the direction that, not only does the context in which recall or recognition occurs matters, such that being in the same context yields improved performance, but how cues are processed and interact during both processes also matter (Uncapher et al., 2006). As such, training and learning instructions directly in the same context in which these instructions need to be performed may yield better results than having the encoding process be in a different context or medium.

There are unique considerations when it comes to learning in virtual environments, as VR can transport learners to different types of environments that provide varying levels of interactivity. As such, users are actively engaging with, rather than passively receiving material. Unlike media such as paper or video, VR allows for embodied actions and control of environmental attributes and behaviors. As such, this active engagement uses cognitive resources. Such affordances ultimately allow for more engagement, as well as contextual and experiential learning (Dalgarno & Lee, 2009), which are critical during the knowledge-construction process (see work under the constructivist theory). In VR, the level of interactivity during training can be considered a form of context, given how central the feature is to the medium.

3. Current Study

While past research focuses on the presence or absence of training or training interventions and how this influences outcomes after a VR experience, very few studies compare the effectiveness of different modalities of training or consider individual differences such as computer anxiety. This study examines the outcomes of people undergoing various types of training prior to engaging with VR-based tasks and narratives. Our research question is as follows: How will training type influence perceptions of using VR for learning for individuals, and will this vary for those with high or low computer anxiety? Participants went through one of three trainings: (a) reading instructions on a paper, (b) watching a video walking through the instructions, or (c) directly experiencing the instructions in VR. Following the training, participants took part in various activities in VR that they had learned in the training and then watched a 360° video. Measures such as recall of VR functions (i.e., mastery of VR functions), content presented in the video (i.e., engagement with the 360° video content), negative VR experience, perception of the effectiveness of training, and ease of completing tasks, were evaluated. Using a large sample size, we consider how individual differences, such as having computer anxiety, may influence perception of VR as well as learning and recall.

4. Methods

4.1. Participants

Participants were from a large public university in the eastern United States. A total of 297 participants underwent both the training and the VR-based portion of the study, and 13 were unable to proceed either due to physical constraints, such as the head-mounted display (HMD) not fitting over glasses or technical difficulties. The 284 participants (male = 149, female = 134, non-binary or other = 1) that were included in this current analysis were between 17 and 31 years old ($M = 19.8$, $SD = 1.62$) and identified as African American ($n = 33$), Asian ($n = 57$), Caucasian/White ($n = 139$), Hispanic ($n = 26$), other ($n = 1$), or did not respond ($n = 28$). Most participants had either no prior experience (32.6%) or very little experience with VR (used 5 or fewer times, 52.5%). Some participants had tried VR many times before (used 5–20 times, 11.7%) and very few had a lot of prior experience (used 20–100 times, 3.2%).

4.2. Hardware

Participants either used a Pico Neo 2 (standalone display with 1920 × 2160 resolution per eye, 101° FOV, 75 Hz refresh rate, and six-degree-of-freedom inside-out head and hand tracking, 350 g) or a Meta Quest 2 (standalone display with 1832 × 1920 resolution per eye, 98° FOV, 90 Hz refresh rate, and six-degree-of-freedom inside-out head and hand tracking, 503 g) and two hand controllers (126 g). A total of 97 participants used Pico Neo 2 HMDs. A switch to Meta Quest 2s ($n = 187$) was made due to the experimental software platform no longer being supported by the former HMD in the middle of the study. Headset type was included as a covariate in our models (see Section 4.7 for details about the models) but was trimmed for robustness, as it was insignificant for the majority of the outcomes. While the switch from one HMD to another was based on platform updates, there is a benefit to generalizing findings across two separate hardware systems.

4.3. Software

Each participant took part in the VR portion of the study in a social VR platform called ENGAGE. In this platform, participants use avatars—embodied visual representations of the participants—to navigate virtual environments. With the hand controllers, participants can translate or teleport around a virtual environment, sit in a virtual chair, draw, and manipulate 3D objects. Participants can also use a virtual tablet or menu to select and add new 3D objects, take pictures, and react using emojis. A private (password-restricted) session was set up for the participants to enter a virtual environment, the "Rooftop Garden (Night)".

4.4. Independent Variable

In this between-subjects study, participants were randomly assigned to one of three training type conditions: paper, video, or VR. Across all conditions, participants underwent similar training tasks on how to navigate a virtual environment using an HMD. In the paper condition, participants, alongside the research assistant, read a guide that was printed on paper. The guide included relevant figures of the software interface. Additionally, the research assistant demonstrated how to use the hand controllers to complete each task (for the written instructions, see Supplementary Material A). In the video condition, participants viewed a video guide presented on a computer screen. The video included instructions on how to use the controllers to complete each task. In the VR condition, the participant, alongside the research assistant, put on HMDs and went into the virtual environment. Inside the virtual environment, the research assistant walked the participant through the tasks and explained how to use the controllers to complete each task.

4.5. Procedure

Before coming to the lab, participants received an information sheet for consent to participate in the university's Institutional Review Board-approved study. They completed a questionnaire (pre-test) covering demographics, computer anxiety, and prior experience with VR. Once at the lab, participants were given the opportunity to ask any questions or concerns about the study. Participants were randomly assigned to one of the three training types (paper, $n = 95$; video, $n = 93$; or VR, $n = 96$). In all conditions, participants were trained to navigate a virtual environment using an HMD.

Following their training, participants put on the HMD to begin the learned tasks. They were advised to stop the study if they felt uncomfortable, uneasy, or any motion sickness at any point. Participants were given steps on how to join the virtual environment, which was set up prior to the study. The HMD content was mirrored onto a desktop computer to allow the research assistants to see what the participants were seeing. Once in the virtual environment, participants were asked to display mastery of the tasks they had learned in the training (see Figure 1). During this time, the research assistant filled out a questionnaire on their perception of the participant's experience, including technological difficulties and mastery of tasks.

Following the tasks, the research assistant transported the participant virtually to a different application to watch a 360° video, *Tour Japan's Ancient History and Modern Marvels in Stunning 360-degree VR* (Discovery, 2017). The 360° video includes graphics displaying cultural historical and contemporary scenes in Japan and includes a narration and walkthrough of the cultural and historic aspects of Japan, such as samurai, fashion, and technology (see Figure 2). This particular 360° video was selected because it is both experientially immersive and has a narrative that presents factual information that is displayed and reinforced in the video. Initial pilot testing showed participants remembered the information presented and were engaged in the video. Once the 360° video was over, the HMD was removed, and participants completed a questionnaire (post-test) on their experience.

Figure 1. Participants were instructed to: (a) walk to the back of the virtual environment until they reached a group of benches around a table; (b) teleport up the stairs and stand next to one of the benches; (c) teleport and sit in one of the bench seats; (d) pull up the tablet, close the tablet, and then open the tablet again; (e) open up the menu and add a teapot 3D object into the virtual environment and place it on the table; (f) pick up the teapot; (g) put the teapot down and open the tablet again to take a picture of the teapot; (h) delete the teapot from the virtual environment; and (i) open the tablet again to use one of the emoji reactions.

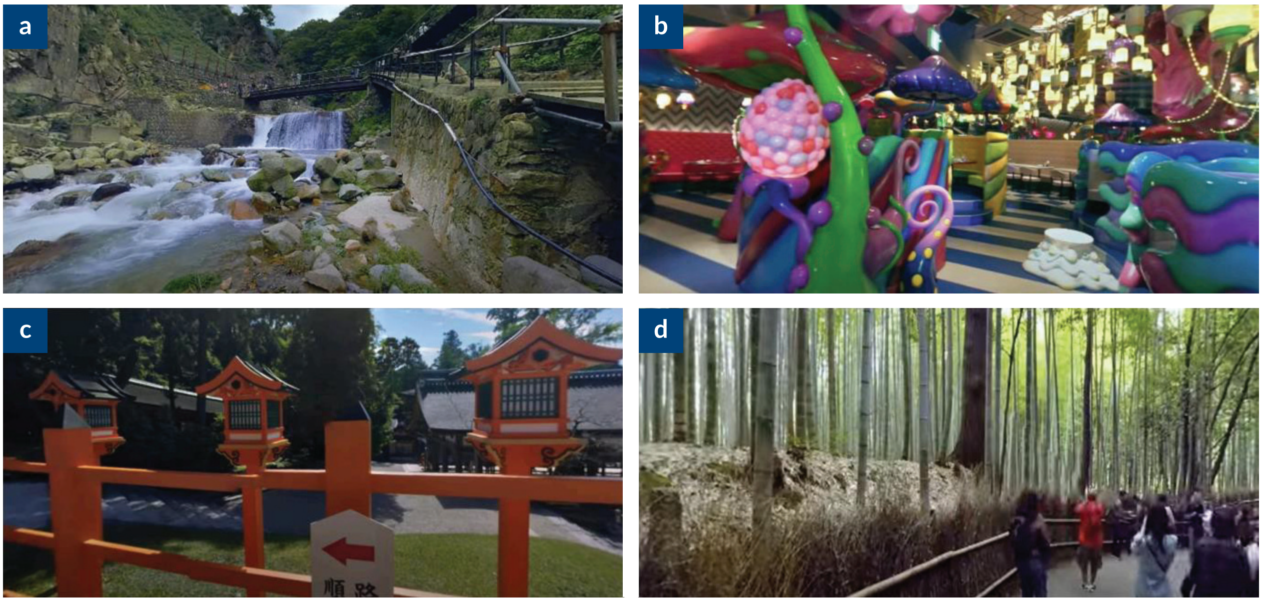

Figure 2. Sample panels from the 360° video where scenes depict (a) fresh water and animals, (b) a fashionable spot in Tokyo, (c) a temple, and (d) a bamboo forest.

Two weeks after the lab experience, participants were sent a link to another questionnaire (delayed post-test) about that day's experience (see Figure 3 for the order and medium of each step of the procedure).

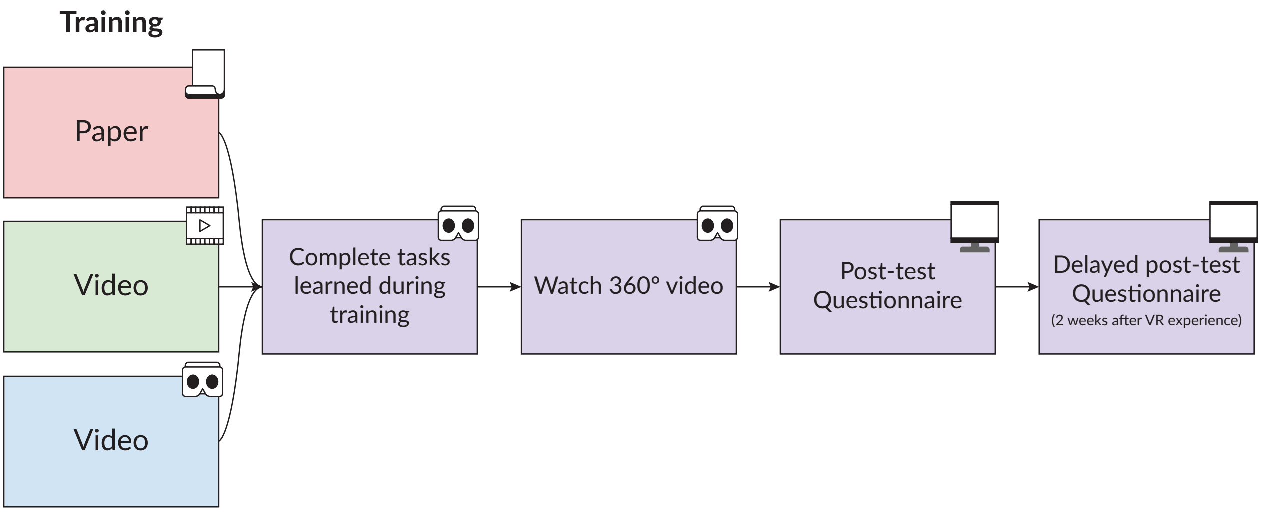

Figure 3. The order and medium in which participants completed each task of the study.

4.6. Measured Variables

Various questions were asked prior to, immediately after, and two weeks after the VR HMD experience. Participants were asked questions about their attitudes and experience in VR. There were additional scales administered during the post-test questionnaire or the delayed post-test questionnaire which we tested, but were not statistically significant: five about attitudes towards the medium (enjoyment, usefulness, positive valence, spatial presence, and realism) and one about simulator sickness. We do not include those analyses in the body of the article due to space constraints, but the statistics are reported in Supplementary Material D.

4.6.1. Computer Anxiety

Computer anxiety was measured prior to the study as an individual difference measure. Computer anxiety was measured by nine items adapted from Torkzadeh et al. (2006; which were developed by Heinssen et al., 1987) using a 7-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). Sample items include "I hesitate to use a computer for fear of making mistakes that I cannot correct" and "I feel insecure about my ability to fix computer-related problems." The means of the nine items were calculated (Cronbach's $\alpha = 0.87$), with higher scores indicating a greater computer anxiety ($M = 2.76$, $SD = 0.93$).

4.6.2. Mastery of VR Functions

Mastery of VR functions was measured as the total number of correct responses to 18 multiple-choice questions about how to perform the tasks participants had learned in the training. These functions were presented during training and participants repeated them during the VR experience. Sample questions included recalling what hand controller was used to teleport, the steps of adding a 3D object into the virtual environment, and the steps of taking a picture. Scores were computed by summing the number of correct answers for each participant ($M = 10.03$, $SD = 4.25$, max = 18, min = 1; for the complete list of questions, see Supplementary Material B).

4.6.3. Engagement with 360° Video Content

Engagement with the 360° video content was measured as the total number of correct responses to nine multiple-choice questions about the material covered by the 360° video. Sample questions included "Which weapon was being crafted by the fire in the video? (Options: Spear, Dagger, Samurai, Katana)" and "The traditional Japanese sport featured in the video is (Options: Jūjitsu, Wrestling, Sumo wrestling, Kendo)." Scores were computed by summing the number of correct answers for each participant ($M = 5.12$, $SD = 1.64$, max = 8, min = 1; for the complete list of questions, see Supplementary Material C).

4.6.4. Negative VR Experience

How negative the participant's experience was in VR was measured by nine items adapted from Torkzadeh et al. (2006) using a 7-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*). The items were adapted to assess whether participants perceived their VR experience as negative. Sample items include "It took a lot of time to figure out how to do things in VR" and "The VR experience was very frustrating." The means of the nine items were calculated (Cronbach's $\alpha = 0.91$), with higher scores indicating a more negative experience ($M = 2.14$, $SD = 0.97$).

4.6.5. Perception of Training

Participants' evaluation of how useful they found the training was measured by six items created for this study using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*). Sample items include "I learned everything I needed during the training" and "I need more training to be successful" (reverse-coded). The means of the six items were calculated (Cronbach's $\alpha = 0.82$), with higher scores indicating that the training was perceived as more useful ($M = 4.32$, $SD = 0.68$).

4.6.6. Self-Rated Perceived Ease of Tasks

Participants' self-evaluation of the perceived ease of completing each task in the social VR platform was measured using a 5-point Likert scale (1 = *extremely difficult*, 5 = *extremely easy*). Sample tasks included sitting in the bench seat or placing a teapot on the table. The means of the seven tasks were calculated, with higher scores indicating that the tasks were completed with more ease ($M = 4.37$, $SD = 0.49$).

4.6.7. Research Assistant-Rated Perceived Ease of Tasks

Similar to the participants' self-evaluation of the perceived ease of completing each task, the research assistant who was present during the study evaluated their perception of the participant's ease of completing each task using a 5-point Likert scale (1 = *extremely difficult*, 5 = *extremely easy*). The means of the seven tasks were calculated, with higher scores indicating that the tasks were completed with more ease ($M = 4.37$, $SD = 0.49$).

4.7. Data Analysis

We used one-way ANOVA with computer anxiety as a covariate (ANCOVA) to model the immediate post-study outcome variables as a function of the independent variable, training type. An interaction term between the covariate and independent variable was tested but trimmed due to insignificance. We additionally tested prior VR experience as a covariate and tested for interactions, but it was insignificant for the majority of the outcomes. Shapiro-Wilk tests were used to test the normality of the data distribution and Levene's test was used to examine the homogeneity of variance. The outcome variables of interest, including transformed data, were found to have a non-normal distribution ($p < 0.05$). Given this, we fit the data using linear mixed-effects models, which yielded the same or similar results. We report the results from the ANCOVA here and provide the output for the linear mixed effects models in Supplementary Material D for comparison. Statistical significance was evaluated at $\alpha = 0.05$. If the ANCOVA indicated differences among the three conditions, post-hoc analyses were conducted to determine the specific differences. The outcome variables were either tested by Tukey's HSD if Levene's test was $p > 0.05$, which is appropriate when performing all pairwise comparisons and is less conservative and more robust to non-normality (Lee & Lee, 2018), or the Games-Howell test if Levene's test was $p < 0.05$, given its robustness to unequal variances (Agbangba et al., 2024).

To assess the changes in participants' responses after two weeks, we conducted a standard RMANOVA. The results are presented by the grand intercept (the average response across training type and time, γ_{00}), the time-related trend (overall change in responses over time, γ_{10}), the main effect of the condition (γ_{20}), and the influence of individual differences in computer anxiety at the initial level (γ_{01}). Any interaction terms, including the interaction between the condition and the individual difference covariate, as well as the interaction between time and condition, were tested and trimmed due to insignificance.

Prior to any analyses, any outcome variables where straight-lining occurred (i.e., selecting the same scale point for all construct items) and cases that were less or greater than three standard deviations (i.e., outliers) were dropped (Müller et al., 2014). All models were fit to the data in R using the "stats" (R Core Team, 2019) and "nlme" packages (Pinheiro, 2024). Post-hoc tests were done using the "emmeans" (Lenth et al., 2024) and "rstatix" packages (Kassambara, 2023). Levene's test was employed using the "car" package (Fox et al., 2023). Figures were generated using the "ggplot2" package (Valero-Mora, 2010).

5. Results

5.1. Mastery of VR Functions

There was a main effect of training type on mastery of VR functions, $F(2,263) = 4.93$, $p = 0.00792$, $\eta_p^2 = 0.04$. Tukey's HSD post-hoc tests revealed significant differences between those in the paper and video training types, as well as those in the paper and VR training types ($ps < 0.05$), such that those who received video and VR training mastered more VR functions (Figure 4a). Additionally, there was a significant main effect of computer anxiety on the outcome variable ($F(1,263) = 14.3$, $p = 0.00020$, $\eta^2 = 0.05$), such that those who had greater computer anxiety had lower mastery of VR functions (Figure 5a).

Results from the delayed post-test showed that the prototypical participant's mastery of VR functions, $\gamma_{00} = 13.1$, $p < 0.000$ (out of 18 functions recalled), did not change significantly, $\gamma_{10} = 0.443$, $p = 0.832$. The significant effect of training type remained after several weeks, such that those who received video training mastered more VR functions, $\gamma_{20} = 0.965$, $p = 0.0463$. Individuals with greater computer anxiety had lower baseline levels of mastery of VR functions, $\gamma_{01} = -1.29$, $p < 0.000$.

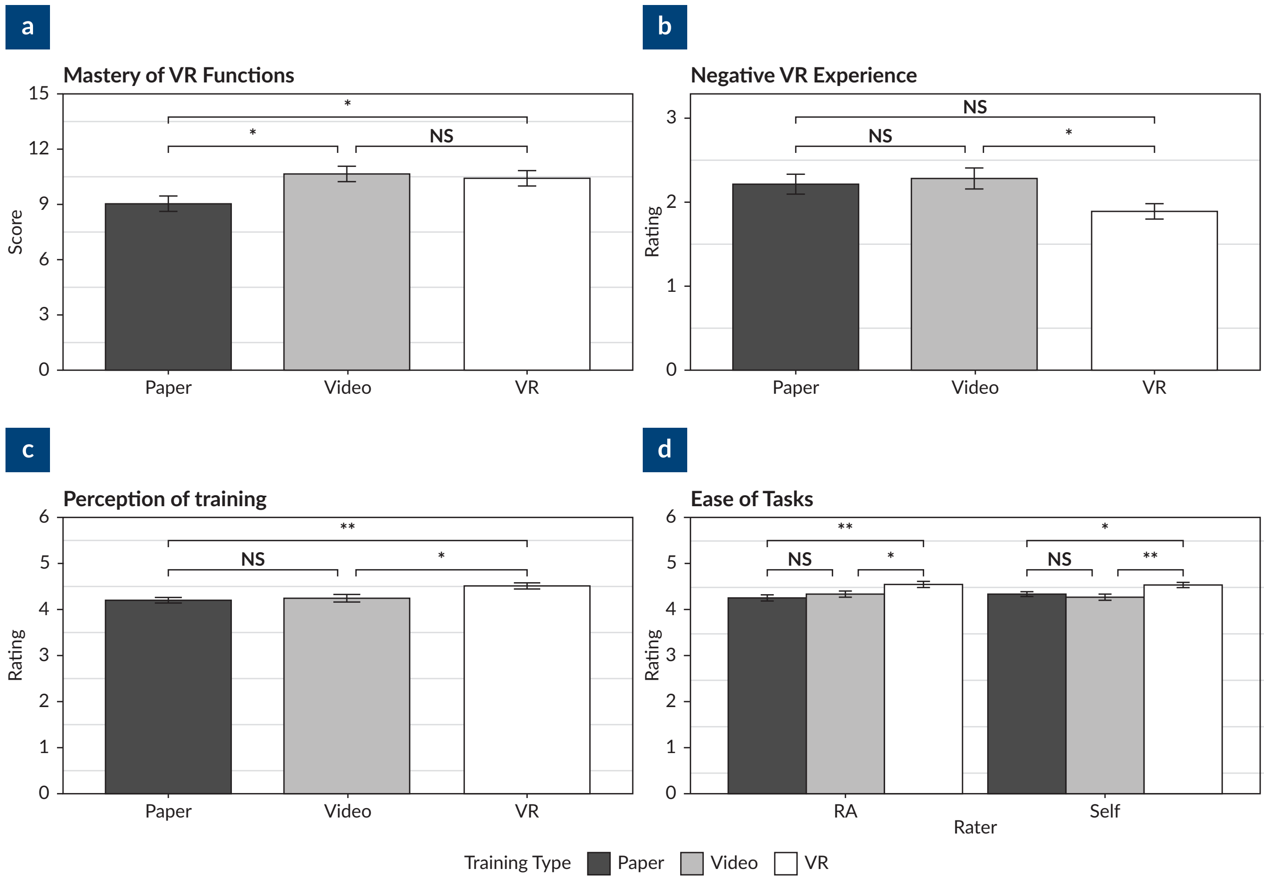

Figure 4. Averages and standard error bars of the outcomes by training type: (a) Average total recall of different controller and action functions in the social VR platform (out of 18), (b) average rating of how negative the VR experience was immediately after and two weeks after the experience (out of 7), (c) average rating of the perceived usefulness of the VR training (out of 5), and (d) average rating of the ease of completing various tasks within the social VR platform (out of 5). Notes: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; NS = not significant.

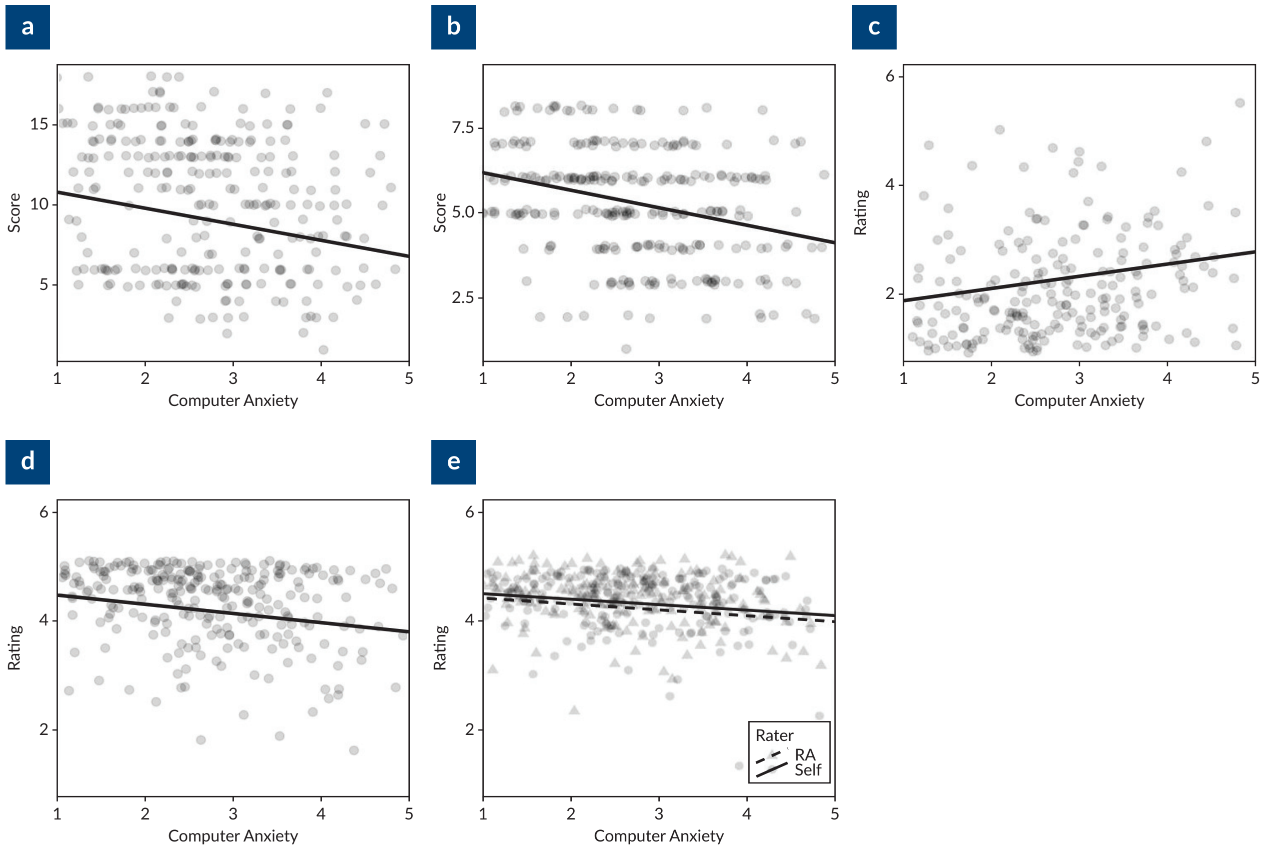

Figure 5. Graphs that represent the relationship between computer anxiety and each outcome variable where (a) is mastery of VR functions; (b) engagement with 360° video content, (c) negative VR experience, (d) perception of training, and (e) ease of tasks. Note: The lines represent the regression line from the ANCOVA models.

5.2. Engagement With 360° Video Content

There was a main effect of training type on engagement with the 360° video content, $F(2{,}262) = 3.24$, $p = 0.04061$, $\eta_p^2 = 0.02$. However, Tukey's HSD post-hoc tests revealed that there were no significant differences when looking at pairwise comparisons (*ps* > 0.0785). There was a significant main effect of computer anxiety on the outcome variable $F(1{,}262) = 26.7$, $p < 0.001$, $\eta^2 = 0.09$, such that those who had greater computer anxiety had lower engagement with the 360° video content (Figure 5b).

Results from the delayed post-test showed that the prototypical participant's engagement with the 360° video content decreased from an initial value of $\gamma_{00} = 6.75$, $p < 0.000$ (out of nine questions recalled), at a rate of $\gamma_{10} = -1.93$, $p < 0.000$ questions. There was no significant effect of training type (*ps* > 0.3094). Individuals with greater computer anxiety had lower baseline levels of engagement with the 360° video content, $\gamma_{01} = -0.5051$, $p < 0.000$.

5.3. Negative VR Experience

There was a main effect of training type on participants' report of how negative their VR experience was, $F(2{,}211) = 4.93$, $p = 0.008068$, $\eta_p^2 = 0.04$. Games-Howell post-hoc tests revealed significant differences between those in the video and VR training types ($p < 0.05$), such that those who received VR training reported having fewer negative VR experiences (Figure 4b). Additionally, there was a significant main effect of computer anxiety on the outcome variable ($F(1,211) = 10.80$, $p = 0.001190$, $\eta_p^2 = 0.05$), such that those who had greater computer anxiety during the pre-test reported having more negative experiences during their time in VR (Figure 5c).

Results from the delayed post-test showed that the prototypical participant's report of how negative their VR experience increased from an initial value of $\gamma_{00} = 1.61$, $p < 0.000$ (on a 7-point scale) at a rate of $\gamma_{10} = 0.443$, $p < 0.000$ points. The significant effect of training type remained after several weeks, such that those who received VR training reported remembering having less of a negative VR experience, $\gamma_{20} = -0.493$, $p = 0.0021$. Individuals with greater computer anxiety had higher baseline levels of negative VR experiences, $\gamma_{01} = 0.261$, $p = 0.0004$.

5.4. Perception of Training

There was a main effect of training type on participants' report of how useful the training was, $F(2,262) = 6.35$, $p = 0.002036$, $\eta_p^2 = 0.05$. Games-Howell post-hoc tests revealed significant differences between those in the paper and VR training types ($p < 0.01$), as well as those in the video and VR training types ($p < 0.05$), such that those who received training in VR reported the training as being more useful (Figure 4c). Additionally, there was a significant main effect of computer anxiety on the outcome variable ($F(1,262) = 15.09$, $p = 0.000130$, $\eta^2 = 0.05$), such that those who had greater computer anxiety reported the training as being less useful regardless of received training type (Figure 5d).

Results from the delayed post-test showed that the prototypical participant's report of how useful the training was increased from an initial value of $\gamma_{00} = 3.29$, $p < 0.000$ (on a 5-point scale) at a rate of $\gamma_{10} = 1.45$, $p < 0.000$ points. The significant effect of training type remained after several weeks, such that those who received VR training reported the training as being more useful, $\gamma_{20} = 0.336$, $p = 0.0006$. Individuals with greater computer anxiety had lower baseline levels of perceived usefulness of the training, $\gamma_{01} = -0.2032$, $p < 0.000$.

5.5. Self-Rated Perceived Ease of Tasks

There was a main effect of training type on participants' report of how easy the VR tasks were $F(2,214) = 6.64$, $p = 0.001601$, $\eta^2 = 0.06$. Tukey's HSD post-hoc tests revealed significant differences between those in the paper and VR training types ($p < 0.05$), as well as those in the video and VR training types ($p < 0.01$), such that those who received training in VR reported the tasks as being easier (Figure 4d). Additionally, there was a significant main effect of computer anxiety on the outcome variable ($F(1,214) = 8.68$, $p = 0.00357$, $\eta^2 = 0.04$), such that those who had greater computer anxiety reported the tasks as being more difficult (Figure 5e).

Results from the delayed post-test showed that the prototypical participant's report of how easy the VR tasks were, $\gamma_{00} = 4.51$, $p < 0.000$ (out of 5 points), did not change significantly, $\gamma_{10} = -0.05053$, $p = 0.296$. The significant effect of training type remained after several weeks, such that those who received VR training reported the tasks as being easier, $\gamma_{20} = 0.2040$, $p = 0.0025$. Individuals with greater computer anxiety had lower baseline levels of perceived ease of tasks, $\gamma_{01} = -0.080044$, $p = 0.0064$.

5.6. Research Assistant-Rated Perceived Ease of Tasks

There were similar results from how the research assistant evaluated the ease with which the participants completed the VR tasks, $F(2,165) = 7.055$, $p = 0.00115$, $\eta_p^2 = 0.08$. Tukey's HSD post-hoc tests revealed significant differences between those in the paper and VR training types ($p < 0.01$), as well as those in the video and VR training types ($p < 0.05$), such that those who received training in VR were evaluated as completing the VR tasks with more ease (Figure 4d). Additionally, there was a significant main effect of computer anxiety on the outcome variable ($F(1,165) = 7.46$, $p = 0.007007$, $\eta_p^2 = 0.04$), such that those who had greater computer anxiety were evaluated as completing the VR tasks with less ease (Figure 5e).

Research assistant-rated reports of perceived ease of tasks were not collected in the delayed post-test. Moreover, there was no significant difference in the self- and research assistant-reports of perceived ease of tasks ($p > 0.05$).

6. Discussion

As people continue to engage in VR in entertainment and educational settings, it is increasingly important to understand how to prepare them to learn and navigate virtual environments. This study examined how different types of training and computer anxiety influence people's ability to learn and engage with narratives and content within VR. Results showed that, compared to participants who received training from paper-based instructions, participants who received training in video or VR mastered more VR functions. Compared to participants who received training in video, those who trained directly in VR had less of a negative VR experience. Furthermore, participants who trained directly in VR perceived the training as being more useful and found the VR tasks to be easier compared to those who received training in paper or video. Finally, most of the outcome variables differed between conditions regardless of time and were still significant several weeks later indicating robustness.

Moreover, while computer anxiety did not interact with the type of training, results showed that those with greater computer anxiety experienced VR differently than those who had lower computer anxiety. Those who had greater computer anxiety had lower mastery of VR functions and engagement with the 360° video content, reported more negative VR experiences, the training as less useful, and the tasks as more difficult. The research assistant also evaluated those with greater computer anxiety as having more difficulty completing the VR tasks.

Evidence of the effectiveness of training in VR and learning how to directly practice the tasks was visible in the open-ended responses of the questionnaire. When asked about their thoughts on completing the various tasks inside the virtual environment, the majority of the participants talked about the ease of certain tasks and the challenges of some of the controls. There were some differences in what detail the participants focused on when describing the helpfulness of the training. Participants who underwent VR training described the training as an opportunity to practice and learn how to do the tasks, or as a walkthrough with the research assistant: "Learning how to do [the tasks] beforehand made [them] easy to do" (P63, VR training). In that vein, some participants commented that it would have been better to have undergone the training inside VR so as to make the process more interactive and more straightforward:

> The instructional video could be replaced by the [research] assistant explaining the controls in real-time, as [the material] would be much easier to take in. When given a large amount of instructional info all at once in a non-intuitive way, you're bound to forget a large amount of it. (P171, video training)

The results are largely consistent with prior literature showing that training prior to using VR could reduce the novelty effect and increase retention (Meyer et al., 2019; Miguel-Alonso et al., 2023). Given those who received training in VR recalled more VR functions and had an easier time completing the tasks, this prior training may have primed them with expectations and information that was not available to those who trained by either reading instructions on paper or watching a video. Those without the direct VR training may have been overwhelmed with the new streams of sensory information and may not have had the resources to process the information presented in VR as effectively (Meyer et al., 2019).

Furthermore, given that people's memory retrieval is better when they are in the same context in which the memory was encoded, participants who encoded the memory directly in VR may have performed the tasks with more ease as they were able to recall better from being in the same context (Godden & Baddeley, 1975; Tulving & Thomson, 1973). Meanwhile, those who received paper or video training had to recall and perform the tasks in a different medium. This difference in the medium in which memory was formed was most likely greater for those who received paper training, as the video training provided a 2D visual walkthrough similar to what one would have seen in VR. This presumably influenced how participants perceived the training. As a result of their performance, those who received VR training perceived the training as being more useful and beneficial, compared to those who received paper and video training.

This aspect of context-dependent memory during the training stage was especially relevant when participants were asked to perform and then recall the VR functions, as the tasks during the training stage were the same. In other words, the cues from the training material interacted meaningfully with the cues during the recall (i.e., mastery) of VR functions (Baddeley, 1982). Context-matching would predict that the training would help for an active, interactive task, but not for a passive watching task. Those who received VR training consequently mastered more VR functions, whereas there were no differences across training types in terms of engagement with the 360° video content.

Moreover, people who are unfamiliar with the technology may have negative experiences because of the novelty of figuring out how to use the device and interacting with the environment. Training directly in VR before performing various tasks and watching a 360° video may have mitigated the novelty and unfamiliarity of the medium (Miguel-Alonso et al., 2023). This, as a result, may have led to perceptions of having less of a negative experience. Meanwhile, those who trained in paper and video were less familiar with the VR technology prior to performing the tasks and watching the 360° video. To them, the novelty and adjustment to the medium may have led to more negative experiences.

Finally, as has been found in previous research, those with greater computer anxiety benefitted less from either type of training and had more negative outcomes. This is consistent with past research showing that computer anxiety can reduce the effectiveness of training (Torkzadeh et al., 2006), such that, despite the main effects of the condition on mastering VR functions and completing tasks with ease, computer anxiety did not interact with the condition, suggesting that no specific form of training helped those with greater computer anxiety more than other forms of training. Rather, all forms of training tested yielded similar results, and the negative outcomes persisted. This is also consistent with past research showing that those who are more apprehensive about technology may allocate more resources to processing and evaluating posed threats (Ahn et al., 2022). Those who had greater computer anxiety may have allocated more resources towards processing other features of VR, rendering them unable to focus as much on remembering and mastering the functions or fully engaging with the video content.

7. Conclusion

7.1. Limitations and Future Directions

There were several events throughout the study that posed limitations. First, several participants noted the value of having a research assistant present in person to troubleshoot challenges or explain steps that the participants could not figure out on their own. The help and presence of another figure may have alleviated potentially negative experiences, or, more broadly, may have shaped the participants' experience. We did not collect information on when (i.e., at what part of the procedure) participants received help from the research assistant. Depending on when and how much participants received help may have played a role in how well-prepared participants felt, and their perception of the training. Future studies should consider whether participants should troubleshoot and navigate technical difficulties on their own or allow research assistants to play a supporting role. Will those who fail to troubleshoot successfully and consequently have a negative VR experience attribute this to insufficient training?

In this vein, although our primary focus was to investigate training types, we had research assistants walk through the instructions and help participants during the paper and VR training types. The helpful role of the research assistant may have played a role in the training experience. Future studies should focus solely on the modalities of training and exclude external factors that could affect training, such as having an instructor or assistant help.

Third, several participants mentioned distractions from the physical world that seeped into their virtual experience. For example, one participant noted that the HMD was mounted too high and they could see the light at the bottom. Another participant, who also noticed the gap, mentioned how distracting this was when looking down. While some physical world distractions may be challenging to account for, such as noise coming from outside, or light seeping in through cracks, given it is already difficult for many to balance visual and auditory information while also navigating around the environment, future studies should aim to reduce any unnecessary distractions.

7.2. Implications

The current study found the beneficial effects of training directly in-headset prior to VR experiences. Results showed that, compared to those who received paper or video training, those who received training in VR had a greater recall of VR functions, reported having less of a negative VR experience, perceived the training as being more useful, and completed tasks with more ease, as rated by both themselves and the research assistant. These findings may be particularly relevant to instructors in an educational setting who want to integrate VR into their curriculum or to filmmakers or entertainers seeking to utilize VR platforms to engage users with their storylines and narratives. This also translates to those developing training and simulations for learning or entertainment purposes. Prior research has shown that learning *how to use* VR before learning *in* VR, as well as ample training, is critical (Han & Bailenson, 2024; Han et al., 2022). However, how this learning via training needed to be administered remained unclear. Our results suggest that keeping the medium the same both during training and doing is ideal. While administering training via paper and videos may reduce the amount of time inside the HMD and thus be more scalable to a larger number of students and requires fewer resources (e.g., teaching staff, finding appropriate training materials), depending on the nature of the VR experience at hand, what this training might look like and how easy it is to administer and scale may change.

Another domain in which this is relevant is storytelling and crafting experiences that are meaningful and memorable. A common issue with first-time VR users is the challenge of knowing where to pay attention to and how to attend to a variety of streams of information. Processing simultaneous streams of information in highly multisensory media like VR can affect how information is processed (Ahn et al., 2022; de Barros & Lindeman, 2013). Many participants mentioned focusing on the engaging graphics or environment and ignoring or missing information presented in the audio narrative. Integrating some form of instructions or training prior to launching a viewer to a narrative may help them understand what the expectations are and how to navigate the experience, especially if there are any interactive components.

Finally, our last implication relates to computer anxiety. Results showed that those with high levels of computer anxiety, in general regardless of training, have more negative outcomes, including less recall of VR functions, having more of a negative VR experience, perceiving the training as being less useful, and completing tasks with more difficulty. This perpetuates an unfortunate situation with negative experiences leading to further increased anxiety. These results raise the question of how those with high computer anxiety can be prepared for VR, if training type does not help them as much as it helps those with less computer anxiety. How can instructors accommodate students who are feeling anxious about using technologies? How can designers of experiences make sure those with high computer anxiety feel included and not left behind from the intended positive outcomes? While this finding demands further research and raises, rather than answers, more questions, it highlights the importance of evaluating this individual difference.

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Conflict of Interests

The authors declare no conflict of interests.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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