Media and Communication
2024 • Volume 12 • Article 8602
https://doi.org/10.17645/mac.8602

ARTICLE

Open Access Journal

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

Mincheol Shin [1] and Heejae Lee [2]

[1] Department of Communication and Cognition, Tilburg University, The Netherlands
[2] Newhouse School of Public Communications, Syracuse University, USA

Correspondence: Mincheol Shin (m.shin@tilburguniversity.edu)

Submitted: 1 May 2024 **Accepted:** 6 September 2024 **Published:** 27 November 2024

Issue: This article is part of the issue "The Many Dimensions of Us: Harnessing Immersive Technologies to Communicate the Complexity of Human Experiences" edited by Nicholas David Bowman (Syracuse University), Dan Pacheco (Syracuse University), T. Makana Chock (Syracuse University), and Lyndsay Michalik Gratch (Syracuse University), fully open access at https://doi.org/10.17645/mac.i455

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.

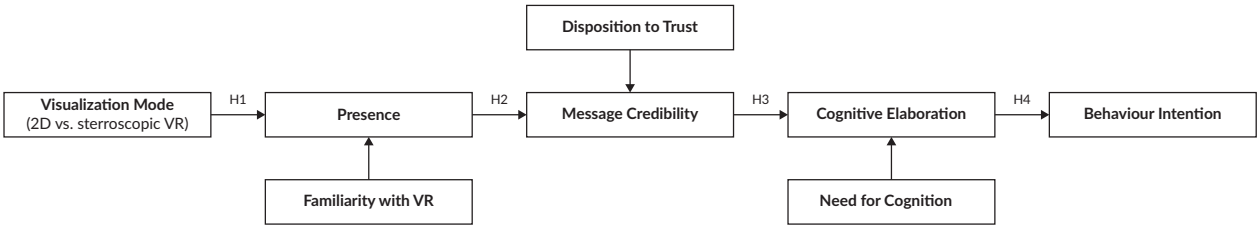

Figure 1. Proposed research model.

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 (η^2 = .51) and commitment to the environment (η^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: $\alpha = .925$; negative elaboration: $\alpha = .997$), 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

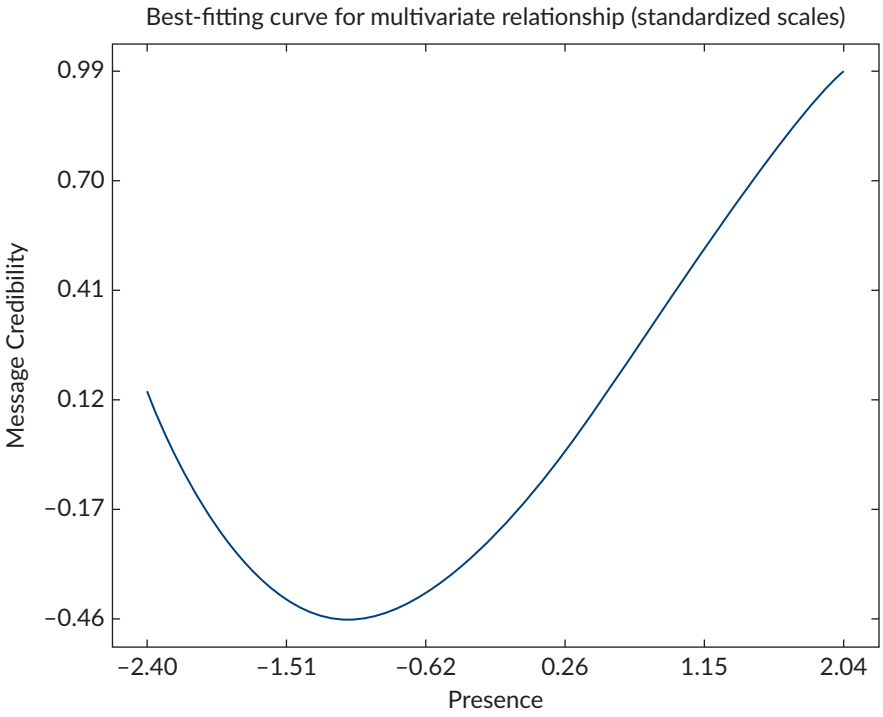

Figure 2. Curvilinear association between presence and message credibility.

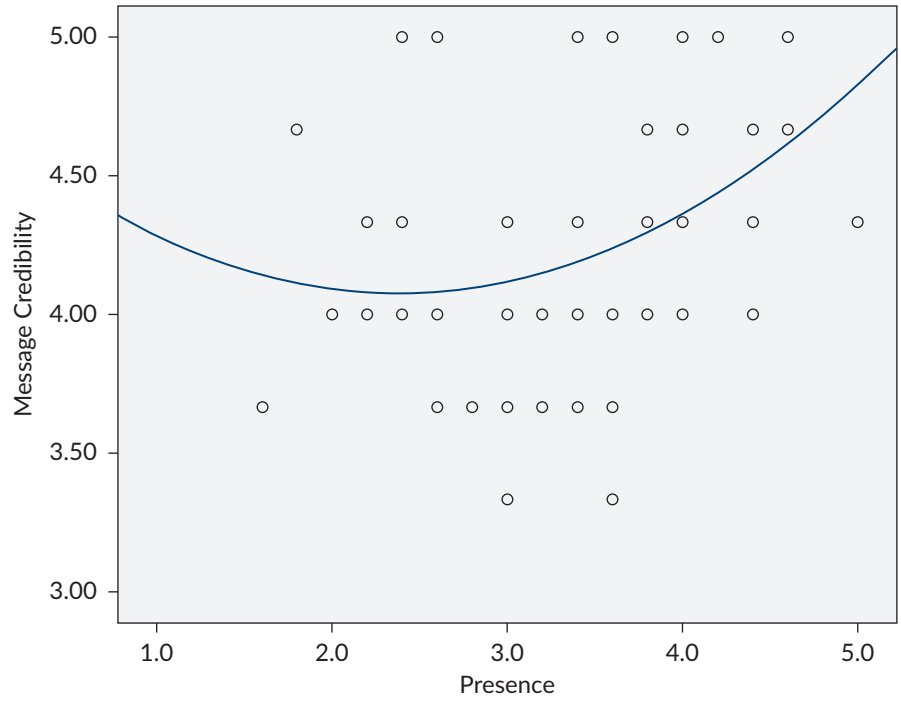

Figure 3. Scatter plot: Unstandardized relationship between raw scores of presence and message credibility. Note: The curvilinear line represents the cubic relationship estimated between presence and message credibility.

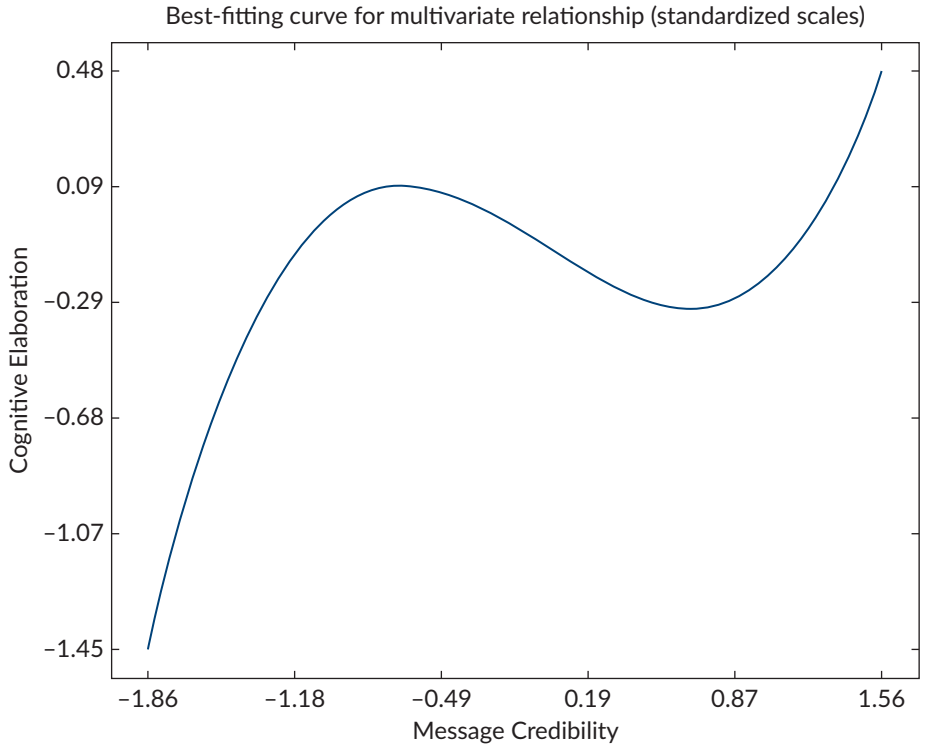

Figure 4. Curvilinear association between message credibility and cognitive elaboration.

is positively, yet curvilinearly, associated with cognitive elaboration ($\beta = .36$, $p = .001$). Notably, need for cognition as a covariate had a positive significant effect on cognitive elaboration ($\beta = .27$, $p = .01$). 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 ($\beta = .25$, $p = .02$). 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.

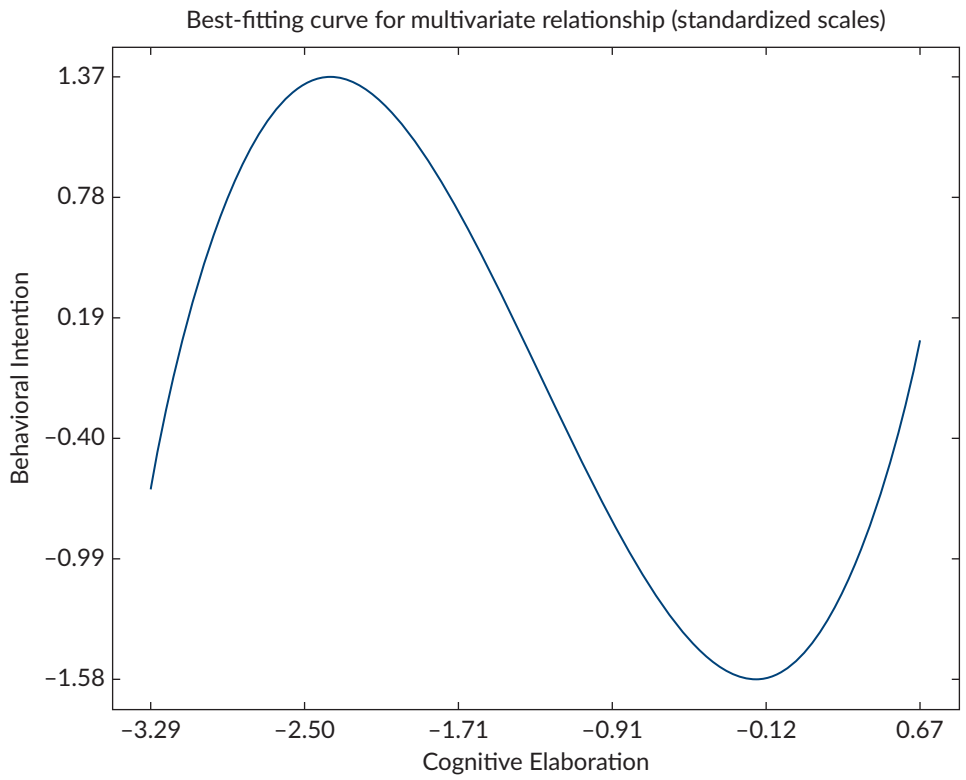

Figure 5. Curvilinear association between cognitive elaboration and behavior intention.

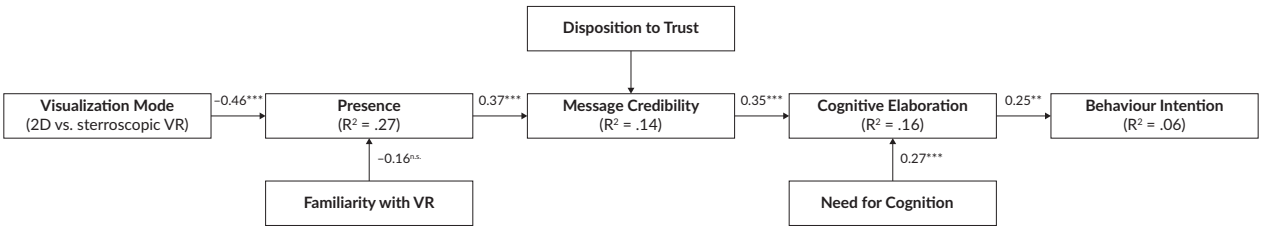

Figure 6. Results of non-linear PLS-SEM model. Notes: * $p < .05$; ** $p < .01$; *** $p < .001$; n.s. = not significant.

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

References

Ahn, S. J. G., Bailenson, J. N., & Park, D. (2014). Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. *Computers in Human Behavior*, *39*, 235–245. https://doi.org/10.1016/j.chb.2014.07.025

Ahn, S. J. G., Nowak, K. L., & Bailenson, J. N. (2022). Unintended consequences of spatial presence on learning in virtual reality. *Computers & Education*, *186*, Article 104532. https://doi.org/10.1016/j.compedu.2022.104532

Amrhein, C., & Balaban, D. C. (2024). The effectiveness of 360° videos for environmental communication. Exploring the impact of different types of storytelling. *Computers in Human Behavior Reports*, *13*, Article 100368. https://doi.org/10.1016/j.chbr.2024.100368

Behm-Morawitz, E., & Shin, H. (2024). Using VR for science communication: Presence, message perception, and pro-environmental effects. *Science Communication*, *46*(1), 36–64. https://doi.org/10.1177/10755470231217535

Biocca, F. (1997). The cyborg's dilemma: Progressive embodiment in virtual environments. *Journal of Computer-Mediated Communication*, *3*(2), Article JCMC324. https://doi.org/10.1111/j.1083-6101.1997.tb00070.x

Bracken, C. C. (2005). Presence and image quality: The case of high-definition television. *Media Psychology*, *7*(2), 191–205. https://doi.org/10.1207/s1532785xmep0702_4

Breves, P. (2021). Biased by being there: The persuasive impact of spatial presence on cognitive processing. *Computers in Human Behavior*, *119*, Article 106723. https://doi.org/10.1016/j.chb.2021.106723

Breves, P. (2023). Persuasive communication and spatial presence: A systematic literature review and conceptual model. *Annals of the International Communication Association*, *47*(2), 222–241. https://doi.org/10.1080/23808985.2023.2169952

Breves, P., & Heber, V. (2020). Into the wild: The effects of 360° immersive nature videos on feelings of commitment to the environment. *Environmental Communication*, *14*(3), 332–346. https://doi.org/10.1080/17524032.2019.1665566

Cacioppo, J. T., & Petty, R. E. (1981). Social psychological procedures for cognitive response assessment: The thought-listing technique. *Cognitive Assessment*, 309–342.

Cacioppo, J. T., & Petty, R. E. (1982). The need for cognition. *Journal of Personality and Social Psychology*, *42*(1), 116–131. https://doi.org/10.1037//0022-3514.42.1.116

Chaiken, S. (1980). Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *Journal of Personality and Social Psychology*, *39*(5), 752–766. https://doi.org/10.1037//0022-3514.39.5.752

Chaiken, S., & Maheswaran, D. (1994). Heuristic processing can bias systematic processing: Effects of source credibility, argument ambiguity, and task importance on attitude judgment. *Journal of Personality and Social Psychology*, *66*(3), 460–473 https://doi.org/10.1037//0022-3514.66.3.460

Cho, Y., & Park, K. S. (2023). Designing immersive virtual reality simulation for environmental science education. *Electronics*, *12*(2), Article 315. https://doi.org/10.3390/electronics12020315

Cinnamon, J., & Jahiu, L. (2023). 360-degree video for virtual place-based research: A review and research agenda. *Computers, Environment and Urban Systems*, *106*, Article 102044. https://doi.org/10.1016/j.compenvurbsys.2023.102044

Evens, M., Empsen, M., & Hustinx, W. (2023). A literature review on 360-degree video as an educational tool: Towards design guidelines. *Journal of Computers in Education*, *10*(2), 325–375. https://doi.org/10.1007/s40692-022-00233-z

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/bf03193146

Feng, Y. (2018). Facilitator or inhibitor? The use of 360-degree videos for immersive brand storytelling. *Journal of Interactive Advertising*, *18*(1), 28–42. https://doi.org/10.1080/15252019.2018.1446199

Fraustino, J. D., Lee, J. Y., Lee, S. Y., & Ahn, H. (2018). Effects of 360 video on attitudes toward disaster communication: Mediating and moderating roles of spatial presence and prior disaster media involvement. *Public Relations Review*, *44*(3), 331–341. https://doi.org/10.1016/j.pubrev.2018.02.003

Fussell, S. G., Derby, J. L., Smith, J. K., Shelstad, W. J., Benedict, J. D., Chaparro, B. S., ... & Dattel, A. R. (2019, November). Usability testing of a virtual reality tutorial. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *63*(1), 2303-2307. Sage CA: Los Angeles, CA: SAGE Publications. https://doi.org/10.1177/1071181319631494

Gefen, D., Karahanna, E., & Straub, D. W. (2003). Trust and TAM in online shopping: An integrated model. *MIS Quarterly*, *27*(1), 51–90. https://doi.org/10.2307/30036519

Goodhue, D. L., Lewis, W., & Thompson, R. (2012). Does PLS have advantages for small sample size or non-normal data? *MIS Quarterly*, *36*(3), 981–1001. https://doi.org/10.2307/41703490

Greussing, E. (2020). Powered by immersion? Examining effects of 360-degree photography on knowledge acquisition and perceived message credibility of climate change news. *Environmental Communication*, *14*(3), 316–331. https://doi.org/10.1080/17524032.2019.1664607

Hair, J. F., Jr., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017). PLS-SEM or CB-SEM: Updated guidelines

on which method to use. *International Journal of Multivariate Data Analysis*, *1*(2), 107–123. https://doi.org/10.1504/IJMDA.2017.10008574

Hair, J. F., Jr., Sarstedt, M., Hopkins, L., & Kuppelwieser, V. G. (2014). Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European Business Review*, *26*(2), 106–121. https://doi.org/10.1108/ebr-10-2013-0128

Hovick, S., Freimuth, V. S., Johnson-Turbes, A., & Chervin, D. D. (2011). Multiple health risk perception and information processing among African Americans and Whites living in poverty. *Risk Analysis*, *31*(11), 1789–1799. https://doi.org/10.1111/j.1539-6924.2011.01621.x

Kock, N. (2022). *WarpPLS user manual: Version 8.0*. ScriptWarp Systems. https://scriptwarp.com/warppls/UserManual_v_8_0.pdf

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Sage. https://doi.org/10.4135/9781071878781

Lee, K. M. (2004). Presence, explicated. *Communication Theory*, *14*(1), 27–50. https://doi.org/10.1111/j.1468-2885.2004.tb00302.x

Lmbard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication*, *3*(2), JCMC321. https://doi.org/10.1111/j.1083-6101.1997.tb00072.x

Ma, C., Au, N., & Ren, L. (2020). Biased minds experience improved decision-making speed and confidence on social media: A heuristic approach. *Information Technology & Tourism*, *22*, 593–624. https://doi.org/10.1007/s40558-020-00184-0

Ma, Z. (2022). The use of immersive stories to influence college students' attitudes and intentions related to drinking and driving. *Journal of American College Health*, *70*(7), 2042–2049. https://doi.org/10.1080/07448481.2020.1842418

Makransky, G., Lilleholt, L., & Aaby, A. (2017). Development and validation of the multimodal presence scale for virtual reality environments: A confirmatory factor analysis and item response theory approach. *Computers in Human Behavior*, *72*, 276–285. https://doi.org/10.1016/j.chb.2017.02.066

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 43–52. https://doi.org/10.1207/s15326985ep3801_6

McKnight, D. H., Choudhury, V., & Kacmar, C. (2002). Developing and validating trust measures for e-commerce: An integrative typology. *Information Systems Research*, *13*(3), 334–359. https://doi.org/10.1287/isre.13.3.334.81

Meijers, M. H., Torfadóttir, R. H., Wonneberger, A., & Maslowska, E. (2023). Experiencing climate change virtually: The effects of virtual reality on climate change related cognitions, emotions, and behavior. *Environmental Communication*, *17*(6), 581–601. https://doi.org/10.1080/17524032.2023.2229043

Nelson, K. M., Anggraini, E., & Schlüter, A. (2020). Virtual reality as a tool for environmental conservation and fundraising. *PLoS ONE*, *15*(4), Article e0223631. https://doi.org/10.1371/journal.pone.0223631

Oh, J., Jin, E., Sudarshan, S., Nah, S., & Yu, N. (2021). Does 360-degree video enhance engagement with global warming?: The mediating role of spatial presence and emotions. *Environmental Communication*, *15*(6), 731–748. https://doi.org/10.1080/17524032.2021.1891945

Oh, J., Khoo, G. S., Lee, J. A., & Sudarshan, S. (2021). Source interactivity enhances sense of community and reduces psychological reactance: Effects of the like button on smoking message evaluations and attitudes. *Journal of Health Communication*, *26*(7), 501–513. https://doi.org/10.1080/10810730.2021.1964008

Oh, J., Sudarshan, S., Jin, E., Nah, S., & Yu, N. (2020). How 360-degree video influences content perceptions and environmental behavior: The moderating effect of environmental self-efficacy. *Science Communication*, *42*(4), 423–453. https://doi.org/10.1177/1075547020932174

Pacini, R., & Epstein, S. (1999). The relation of rational and experiential information processing styles to personality, basic beliefs, and the ratio-bias phenomenon. *Journal of Personality and Social Psychology*, *76*(6), 972–987. https://doi.org/10.1037//0022-3514.76.6.972

Pehlivanides, G., Monastiridis, K., Tourtas, A., Karyati, E., Ioannidis, G., Bejelou, K., Antoniou, V., & Nomikou, P. (2020). The virtualdiver project. Making Greece's underwater cultural heritage accessible to the public. *Applied Sciences*, *10*(22), Article 8172. https://doi.org/10.3390/app10228172

Petty, R. E., & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. *Advances in Experimental Social Psychology*, *19*, 123–205. https://doi.org/10.1016/s0065-2601(08)60214-2

Pimentel, D., & Kalyanaraman, S. (2023). Virtual climate scientist: A VR learning experience about paleoclimatology for underrepresented students. *Interactive Learning Environments*, *31*(7), 4426–4439. https://doi.org/10.1080/10494820.2021.1969582

Plechatá, A., Morton, T., Perez-Cueto, F. J., & Makransky, G. (2022). A randomized trial testing the effectiveness of virtual reality as a tool for pro-environmental dietary change. *Scientific Reports*, *12*(1), Article 14315. https://doi.org/10.1038/s41598-022-18241-5

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators & Virtual Environments*, *6*(6), 603–616. https://doi.org/10.1162/pres.1997.6.6.603

Sneed, J. C., Deringer, S. A., & Hanley, A. (2021). Nature connection and 360-degree video: An exploratory study with immersive technology. *Journal of Experiential Education*, *44*(4), 378–394. https://doi.org/10.1177/10538259211001568

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

Sundar, S. S. (2008). The MAIN model: A heuristic approach to understanding technology effects on credibility. In M. J. Metzger & A. J. Flanagin (Eds.), *Digital media, youth, and credibility* (pp. 73–100). MIT Press.

Virtual Human Interaction Lab. (2019, November 5). *Coral compass: Fighting climate change in Palau* [Video]. YouTube. https://www.youtube.com/watch?v=ipzcXbCytlc

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., Saari, T., Laarni, J., Ravaja, N., Ribeiro Gouveia, F., Biocca, F., Sacau, A., Jäncke, L., Baumgartner, T., & Jäncke, P. (2007). A process model of the formation of spatial presence experiences. *Media Psychology*, *9*(3), 493–525. https://doi.org/10.1080/15213260701283079

About the Authors

Mincheol Shin is an assistant professor of new media design at Tilburg University, The Netherlands. His research focuses on the psychological effects of emerging media technologies on human cognition, information processing, and behaviors.

Heejae Lee is a PhD candidate at the S. I. Newhouse School of Public Communications at Syracuse University. His research centers on discovering how the interactivity of media technologies and individual heuristics shape user perceptions.