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How virtual reality shapes visitor experiences during the pre-visit stage: The role of perceived realism☆

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ABSTRACT

Virtual reality (VR) may enhance the pre-visit phase of the visitor journey by allowing would-be tourists to preview destinations and promoting the value of their experience and their well-being. The realism of VR experiences plays a key role at this stage, yet current research reveals mixed findings. Grounded in the stimulus–organism–response model, this study investigates how VR content with different levels of realism influences affective responses and, in turn, shapes visitor intentions and behaviors during the pre-visit phase. A laboratory experiment using a multimethod approach combining self-reported, neurophysiological, and behavioral measures revealed that VR experiences elicit psychophysiological activation closely associated with affective responses, highlighting the potential of immersive technologies to enhance the pre-visit experience. Furthermore, although high realism enhances perceived authenticity, less realistic VR environments are more effective in stimulating travel intentions and engagement with the tourist place. Practical insights are offered for businesses in the tourism sector.

1. Introduction

Virtual reality (VR) promises engaging experiences along the customer journey by enhancing experiential value. This is especially relevant for industries centered on intangible offerings, such as tourism and hospitality (Thaichon et al., 2024). Tourism experiences often involve uncertainty because outcomes cannot be fully anticipated, representing a psychological barrier to purchase (Lee et al., 2021). In contrast to other digital technologies that offer preliminary information about destinations, VR provides embodied immersion, enabling users to explore environments interactively (Guttentag, 2010; Tussyadiah et al., 2018). This level of sensory richness and sense of presence distinguishes VR from traditional media, such as websites, videos, or static virtual tours, making it particularly valuable for studying pre-visit evaluations (Di Dalmazi et al., 2024). Thus, tourism businesses are increasingly adopting VR as a marketing and engagement tool (Casais et al., 2025). VR allows potential customers to preview destinations (e.g., cultural heritage sites, natural parks, or hotel facilities) during the pre-visit stage through immersive virtual tours that emulate an actual exploration of the space, as if the person is immersed there (Flavián et al., 2019). This familiarity reduces uncertainty (Tussyadiah et al., 2018) and anticipates emotional connections with a place. Furthermore, pre-visit expectations shaped by VR influence how visitors acquire knowledge and evaluate their subsequent real-world experiences (Kostyk et al., 2024). Although VR is intended to encourage actual visits, evidence suggests it can sometimes have the opposite effect (Deng & Lee, 2019).

Immersive technologies may influence not only physical access to destinations during the pre-visit stage but also the psychological processes that shape visitors' early evaluations and emotional states. Furthermore, VR can enhance well-being by offering multisensory environments that provide restorative, stress-reducing experiences (Chirico et al., 2023, 2024; Ma et al., 2023; Melo et al., 2020, 2022). Safety in tourism includes physical and psychological safety. VR may foster feelings of control and emotional reassurance by allowing visitors to engage with unfamiliar destinations in a risk-free setting. Nonetheless, high levels of immersion may elicit discomfort, anxiety, or sensory overload for some users (Tarafdar et al., 2019). These mixed reactions suggest that VR may overcome certain barriers while introducing new

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psychological challenges. Recent research shows that virtual tourism also elicits psychophysiological responses, such as changes in brain activity or cardiac patterns (Zhang & Xiao, 2024). These responses mirror those evoked by physical travel, suggesting that VR can replicate some aspects of the real world on a physiological level. By offering a form of mental escapism, VR can reduce stress and support overall well-being (McLean et al., 2023). For instance, realistic virtual environments, such as forests, lakes, or beaches, have been linked to restorative effects, including improved mood and reduced fatigue (Spano et al., 2023).

The perceived realism of the VR experience has been acknowledged as a relevant aspect influencing the overall experience (McLean & Barhorst, 2022; Spielman & Orth, 2021). However, the emotional and behavioral outcomes of VR realism remain mixed, especially before visiting an actual environment. Although highly realistic formats, such as 360° VR videos (360-VR), can elicit strong emotional responses (Jai et al., 2025; Orús et al., 2021), they may also lead users to perceive the experience as a full substitute for the real one, reducing actual consumption intent (Deng et al., 2019). By contrast, the use of fully synthetic digital environments (FD-VR), though less realistic, has been linked to increased willingness to travel and social engagement (Kang et al., 2021; Ogrizović & Hadžić, 2021; Tussyadiah et al., 2018). Furthermore, some studies have found only minimal differences between immersive VR headset previews and 360-VR experiences, adding complexity to our understanding of the role realism plays in virtual environments (McLean & Barhorst, 2022). For companies, selecting between 360-VR and FD-VR requires an understanding of how each technology shapes users' pre-visit perceptions and supports specific communication or experiential goals. Moreover, a key limitation is the reliance of many studies on self-reported measures, which are prone to biases, such as social desirability, and cannot fully capture the affective states influencing user responses (Bettiga et al., 2017). Even though self-reports are valuable for assessing consumer evaluations and intentions, they are unlikely to identify processes that underpin behavior. Bridging this gap is fundamental, given the crucial role of physiological and affective responses in decision-making, particularly in multisensory and immersive experiences, such as those offered through VR (Flavián et al., 2021a).

Therefore, this study examines how VR experiences with varying degrees of realism influence affective responses and shape visitors' intentions and behaviors during the pre-visit phase of the tourism journey. This investigation is grounded in the stimulus–organism–response model, a well-suited framework for exploring how external stimuli affect consumer processing and behavioral outcomes (Kim et al., 2020; Mauri et al., 2024; Mehrabian & Russell, 1974). We conducted an experiment using a multimethod approach combining self-reported, neurophysiological, and behavioral data to assess consumer responses to virtual experiences. This study advances our knowledge of the impact of VR on consumers' experiences (Dwivedi et al., 2022) by investigating the mechanisms leading to visitors' intention and behavior formation during the pre-visit phase (Flavián, et al., 2021b) and addressing mixed findings on the role of realism (McLean & Barhorst, 2022). Methodologically, the study responds to calls for more objective assessments of VR experiences (Orús et al., 2021) and offers practical acumen for tourism businesses.

2. Theoretical background and hypotheses development

This study employs the stimulus–organism–response model as its overarching framework. Since its early introduction (Mehrabian & Russell, 1974), the model has been adapted to study user behavior across various fields, from distance education to retail, and has been extensively used to investigate visitors' experiences with VR (Erensoy et al., 2024; Kim et al., 2020; Liu & Huang, 2023; Sann et al., 2024). The stimulus–organism–response framework is especially suitable for examining consumers' responses to VR experiences, as it allows researchers to understand how users process the interface characteristics of VR, such as realism, and how these internal states shape behavioral outcomes. Moreover, the model considers a range of psychophysiological processes (Talwar et al., 2023), and is thus an appropriate framework for understanding the complex mechanisms underlying the travel experience.

In this study, the stimulus relates to the degree of realism offered by the VR experience, contrasting a high-fidelity 360-degree photogrammetric VR environment with a fully computer-generated VR environment. Such differences in realism become more relevant as VR technologies gain prominence among tourism providers, as they may elicit distinct cognitive and emotional responses from users (Kim et al., 2020; Slater & Sanchez-Vives, 2016). The organism component refers to the consumer's internal processing during the experience, including the perceived sense of presence and physiological responses (Kisker et al., 2021; Orús et al., 2021). These responses can be either positive (e.g., enjoyment) or negative (e.g., discomfort) and are shaped by how individuals perceive the virtual environment. Lastly, the response dimension encompasses users' behavioral outcomes, including their level of engagement with the destination and their willingness to visit in the future (Kim & Hall, 2019; Lee et al., 2021). Fig. 1 illustrates the conceptual framework guiding this study.

2.1. Physiological responses and sense of presence across different degrees of VR realism

VR is defined as a simulated, immersive environment designed to engage one or more human senses, most commonly vision and hearing, and, increasingly, touch (Fan et al., 2022; Kang et al., 2020). Since its conceptualization, VR has revolved around three key components: a sense of immersion, response to user actions, and real-time 3D graphics (Zheng et al., 1998). These components allow users to experience sensory stimulation in real time (Fan et al., 2022; Flavián et al., 2019; Guttentag, 2010; Kang et al., 2020; Schuemie et al., 2001). VR content varies in its degree of realism, typically taking the form of either synthetic environments or 360-degree video (Beck, 2019). Of these, 360-VR tends to offer realistic depictions of real-life experiences (Cheng et al., 2022). By contrast, FD-VR experiences are created using computer-generated graphics, offering a simulation-like quality that prioritizes sensory richness over photorealism.

The sensory richness that characterizes FD-VR environments encourages user engagement but may also place substantial cognitive demands on users because of the high perceptual load (Leung et al., 2020). Perceptual load refers to the cognitive demands placed on an individual's sensory processing capacity that increase with the volume and complexity of sensory stimuli in the environment (Fisher et al., 2018; 2019). Research has shown that perceptual load affects attentional processes in FD-VR (Mandolfo et al., 2025). Moreover, the technostress theory (Souchet et al., 2023; Tarafdar et al., 2019) suggests that users may experience strain when attempting to adapt to complex digital systems. The heightened perceptual demand of FD-VR environments can result in overwhelming experiences, reducing the pleasure users derive from the interaction (Stein & Ohler, 2017). On the other hand, the sensory richness offered by FD-VR can foster deep involvement and sustained attention (Jennett et al., 2008; Shin, 2018). Thus, the higher immersive potential of FD-VR is expected to foster higher levels of user engagement (Jennett et al., 2008).

More broadly, immersive VR environments are expected to activate psychophysiological processes because they expose users to multisensory stimulation (Kim et al., 2020; Mauri et al., 2024). In tourism settings, these mechanisms are particularly relevant during the pre-visit phase, where immersive previews may shape anticipatory responses before the actual visit. Hence, we expect that exposure to VR tourism experiences during the pre-visit stage will elicit measurable physiological responses. Also, we assume that the 360-VR and FD-VR experiences trigger different physiological responses. FD-VR experiences are expected to induce higher levels of attention, engagement, and arousal

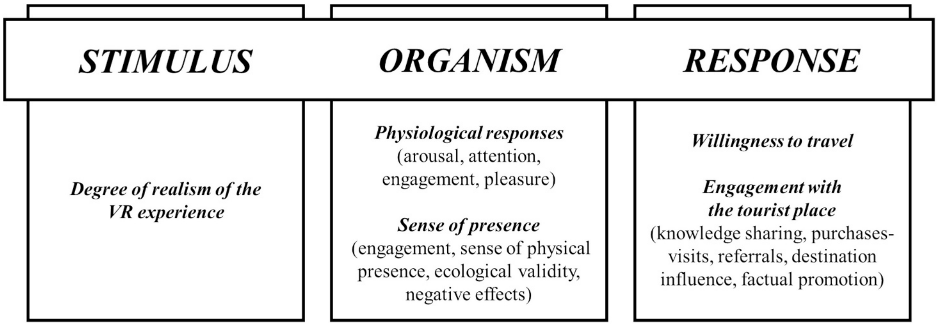

Fig. 1. Reference conceptual framework.

than 360-VR because users interact with sensory-rich virtual environments. However, such environments may also hinder physiological responses related to pleasure, despite high levels of involvement, because of the perceptual load associated with navigating the virtual space. Therefore, we propose the following explorative hypotheses:

H_1: Exposure to VR tourism experiences during the pre-visit phase elicits marked physiological responses, compared to baseline conditions.

H_2: FD-VR experiences generate higher physiological responses of (a) arousal, (b) attention, and (c) engagement and lower physiological responses of (d) pleasure than 360-VR experiences.

A defining feature of VR is its ability to elicit a sense of presence, commonly described as "the perceptual illusion of non-mediation" (Lombard & Ditton, 1997; Waterworth et al., 2015). According to Kim and Biocca (1997), presence embodies the user's psychological perception of being transported elsewhere. A high sense of presence results in consumers responding emotionally as if the environment existed in reality (Waterworth et al., 2015). Presence has been extensively assessed through the ITC-Sense of Presence Inventory (ITC-SOPI), a self-report instrument that conceptualizes it as the aggregate of four perceptual dimensions: engagement, spatial presence, ecological validity, and negative effects (Lessiter et al., 2001). Engagement depicts the individual's interest and participation in the experience, whereas spatial presence reflects the perception of being physically in the mediated environment. Ecological validity refers to the perceived authenticity of the virtual setting, and negative effects encompass discomfort that may arise from the encounter.

Different levels of VR realism are expected to affect the degree of presence experienced by users. Low-realism FD-VR systems, which respond to real-time input and incorporate videogame-like mechanics, encourage exploration and user engagement. This responsiveness also strengthens the illusion of being physically situated within the environment, increasing the sense of spatial presence (Tussyadiah et al., 2018). By contrast, 360-VR is filmed in actual environments and presents visually realistic scenes, so it is expected to yield higher ecological validity (Martínez-Navarro et al., 2019). FD-VR, being computer-generated and often less photorealistic, is assumed to display lower ecological validity because of its artificial visual cues. The low realism and videogame-like characteristics of FD-VR environments may also induce negative effects, such as discomfort. These reactions often stem from conflicting sensory inputs, such as mismatches between visual and vestibular stimuli that induce motion sickness (LaViola, 2000). Symptoms of cybersickness, such as nausea and dizziness, are especially troublesome in tourism contexts, where comfort and enjoyment are central to the user experience. Furthermore, the lower realism of FD-VR, compared to 360-VR, can contribute to a dissonant experience, worsening discomfort (Stein & Ohler, 2017). These divergences suggest that the VR typology may affect the individual's emotional and behavioral responses, as proposed in the following hypotheses:

H_3: FD-VR experiences induce higher engagement than 360-VR experiences.

H_4: FD-VR experiences induce a higher sense of physical space than 360-VR experiences.

H_5: 360-VR experiences yield higher ecological validity than FD-VR experiences.

H_6: FD-VR experiences induce greater perceived negative effects than 360-VR experiences.

2.2. Willingness-to-travel and engagement with the tourist destination

The impact of VR experiences on visitors' behavioral intentions is a central theme in immersive tourism research. VR enhances cognitive processing through mental imagery and a heightened sense of presence (Bogicevic et al., 2019), which, in turn, impacts users' evaluations and intentions (Fan et al., 2022). VR fosters visit intention (Kim et al., 2020; Skard et al., 2021; Tussyadiah et al., 2018), revisit intention (Kusumah et al., 2022; McLean & Barhorst, 2022), and intention to recommend (Jorge et al., 2023; Sousa et al., 2024). These often arise from personal beliefs about the tourism offering, social cues, and situational factors occurring during the different steps of the travel journey (Khan et al., 2019; Sparks & Pan, 2009).

Willingness to travel refers to an individual's perceived likelihood of visiting a destination within a given timeframe (Ahn et al., 2013; Khan et al., 2019; Woodside & Lysonski, 1989). Willingness to travel—an attitudinal intention— is a precursor of actual travel behavior (Kozak, 2001); it also encompasses the willingness to revisit or re-experience a destination (Tosun et al., 2015; Zeithaml et al., 1996). For instance, consumers have demonstrated a higher intention to visit a hotel after engaging with an immersive VR preview (McLean & Barhorst, 2022). In addition, different levels of realism elicit distinct physiological and behavioral responses (Tefurth et al., 2024). Together with ongoing research on psychophysiological reactions to realistic versus less realistic interactions, this finding provides a foundation for understanding how realism influences user experience in virtual environments. However, the role of realism in shaping these outcomes remains inconclusive. Realistic virtual encounters stimulate immediate action and promote further engagement with virtual experiences (Cheng et al., 2022; Jai et al., 2025; Orús et al., 2021). However, a substantial body of research underlines that immersive VR induces stronger emotional responses, increasing the intention to engage with a destination offering (Kang et al., 2021; Tussyadiah et al., 2018). Feeling immersed in a virtual environment may increase the enjoyment of the experience, resulting in a positive attitude and greater visit intention (Tussyadiah et al., 2018). Furthermore, satisfaction and engagement with the destination are known drivers of future visit likelihood (Rafi et al., 2024). Therefore, even though realism may contribute to authentic responses, we argue that the immersive qualities of FD-VR experiences are more likely to enhance users' willingness to travel than 360-VR experiences. Hence, we propose:

H_7: FD-VR experiences result in a greater willingness to travel than 360-VR experiences.

Engagement with the destination involves four components: knowledge sharing, which reflects a willingness to offer feedback to improve the destination; purchases/visits, indicating satisfaction derived from the visit; referrals, which allude to the intent to recommend the destination to others, helping attract visitors, thus contributing to value-creation for the location; and influence, which is the impact the visitor makes by sharing their experiences and highlighting the destination's benefits, influencing other consumers' activities (Kumar & Pansari, 2016; Loureiro & Sarmento, 2019; Orús et al., 2021).

Immersive VR experiences enhance these forms of engagement by promoting stronger cognitive and affective responses, increasing user involvement and willingness to offer suggestions (Tussyadiah et al., 2018). Wei et al. (2019) were among the first to assess the influence of VR experiences on the willingness to recommend a destination, revealing the positive impact of the sense of presence on intentions to recommend a tourist destination. VR experiences stimulate prosocial behaviors, such as sharing valuable feedback (Jung & Dieck, 2017; Loureiro et al., 2020) and destination advocacy post-visit (Prayag et al., 2017). Recently, Rafi et al. (2024) showed that 360-VR influences consumer engagement and satisfaction, leading to positive word-of-mouth recommendations. This outcome may be due to the realistic nature of 360-VR, which is filmed in real-world settings and conveys factual, lifelike experiences (Cheng et al., 2022), potentially fostering knowledge-sharing behaviors and feedback intended to support destination improvement. By contrast, FD-VR environments, while typically less realistic, can generate heightened emotional arousal and excitement, which have been linked to increased engagement and a stronger intent to promote the destination (Kang et al., 2021; Tussyadiah et al., 2018). Virtual tourism may also promote pro-environmental behavior in consumers (Wu & Wang, 2025). Recent research shows that the immersive and engaging nature of the VR tourism environment fosters visitors' eco-friendly behavior by enhancing the perceived relevance of environmental consequences (Su et al., 2024). Thus, immersive and emotionally engaging experiences, such as the ones accessible in FD-VR environments, may motivate consumers to promote destination preservation. Therefore, we propose the following hypotheses:

H_8: 360-VR experiences induce greater knowledge sharing than FD-VR experiences.

H_9: FD-VR experiences result in greater purchases/visits than 360-VR experiences.

H_{10}: FD-VR experiences encourage greater destination referrals than 360-VR experiences.

H_{11}: FD-VR experiences yield higher destination influence than 360-VR experiences.

H_{12}: FD-VR experiences prompt greater promotion of destination preservation than 360-VR experiences.

It should be noted that visitors' characteristics and cultural influences, along with contextual factors, such as destination typology and the context of use, may impact how VR influences sense of presence, affective responses, and behavioral intentions. Variables such as age, gender, expertise, and familiarity with the content affect outcomes, including cybersickness, although findings are mixed (Dilanchian et al., 2021; Petri et al., 2020). The type of destination also plays a role; for example, virtual experiences of natural environments may be more calming and restorative than those set in urban contexts (Valtchanov & Ellard, 2010). Examining these moderating effects is beyond the scope of the present work; however, future research seeking to deepen the framework developed herein may look into them.

3. Methodology

3.1. Experimental design

We employed a between-subjects experimental design with two treatment conditions (high vs. low realism), each presenting the same panorama of the Fondo Toce Nature Reserve in Verbania, Piedmont, northern Italy. The site was selected because it was designated by UNESCO as part of the Ticino Val Grande Verbano Biosphere Reserve, making it comparable to destinations commonly examined in tourism research (Kim et al., 2019). Moreover, the reserve includes key environmental features, such as green and blue spaces and open landscapes that are central to studying user experience in nature-based and restorative tourism contexts (White et al., 2010). Both treatments were delivered through a head-mounted display and maintained identical perspectives in terms of height, width, and weather conditions. The virtual environment included the entrance of the reserve and a single navigable path, leading to a final point where participants encountered the lake. This pathway was selected because it mirrors the most common visitor route used to access the panoramic area in the actual destination, ensuring comparability with real-world tourist behavior. Furthermore, employing a pre-defined path allowed us to standardize exposure across conditions, ensuring that participants encountered the same sequence of environmental stimuli while isolating the effect of realism. The level of behavioral interactivity was kept constant and low, as users could not alter the environment, in line with tourism pre-experiences, where visitors cannot modify the destination (Orús et al., 2021).

Under the high-realism condition, participants were exposed to a 360-VR environment, allowing them to explore the panorama as a realistic video environment. This video was created using the Insta360 X3 Pocket 360 Action Cam, capturing real footage from the nature reserve (see Figs. 2 and 3 for a visual reference). The low-realism condition involved an FD-VR environment developed in Unity (see Figs. 4 and 5). Both conditions involved the use of a head-mounted display (Meta Quest 2), providing a high degree of technological embodiment and ensuring immersive experiences that engaged participants affectively and sensorially (Flavián et al., 2019).

3.2. Sample and procedure

The experimental activity took place in a controlled laboratory setting and involved 58 participants (60.3% women, $M_{age} = 23.2$, $SD = 1.59$, age range: 19–28). Regarding educational background, 12.1% held a high school diploma, 43.1% a bachelor's degree, and 44.8% a master's degree. Also, 62.1% of participants reported having previous experience with VR using head-mounted displays. Concerning technology use, 13.8% of participants rated their technological skills as poor, 37.9% as intermediate, 43.1% as good, and 5.2% as excellent. Furthermore, participants demonstrated high levels of technology readiness, reporting strong familiarity with the use of innovative technologies ($M = 4.36$, $SD = 0.93$). This demographic profile aligns with the typical user base of emerging technologies (Sanders et al., 2024) and is in line with the samples employed in previous studies on the use of VR in tourism (Lo et al., 2020; Zhu et al., 2024). Moreover, early adopters and frequent users of VR technologies tend to be young adults, who represent an

Fig. 2. Participant's view in 360-VR, showing the navigable path through the natural environment.

Fig. 3. Participant's view in 360-VR, showing the lake area at the end of the path.

Fig. 4. Participant's view in FD-VR, showing the navigable path through the natural environment.

Fig. 5. Participant's view in FD-VR, showing the lake area at the end of the path.

important target demographic for immersive tourism experiences (Robaina-Calderín et al., 2023). All participants reported that they had not visited and were not familiar with the Fondo Toce Nature Reserve. Also, the sample size was selected in accordance with prior research employing electroencephalography combined with head-mounted displays (Kakaria et al., 2023; Saffari et al., 2023). A recent systematic review on electroencephalography usability in marketing research indicates that typical sample sizes in this field range from 16 to 42 participants (Bazzani et al., 2020). Participants were recruited via social media advertisements and convenience sampling, which facilitated the inclusion of healthy individuals, ensuring suitability for recording physiological signals.

The experimental procedure followed several sequential steps. First, a laboratory assistant introduced participants to the study's objectives and obtained their written informed consent. Participants then received instructions on how to navigate the virtual environment, followed by an orientation session conducted in a practice setting. This setting differed from the actual test environment in both content and scale, allowing participants to familiarize themselves with the virtual experience and navigation controls. Next, participants were fitted with physiological sensors, and baseline measurements were recorded. Initially, participants were instructed to close their eyes for 120 seconds, followed by a 180-second exposure to a static black cross displayed on a 24" computer monitor. After this baseline phase, participants completed a questionnaire that collected psychographic data. Subsequently, they were fitted with the VR head-mounted display. Fig. 6 displays the experimental setup. Next, participants began exploring the virtual environment assigned (360-VR or FD-VR). The experience began at the entrance of the natural reserve, where participants were instructed to follow a designated path and to freely explore the surroundings. Upon reaching the final point facing the lake, they remained stationary for 120 seconds, during which they could look around freely (360° head movement) but could not alter their position along the path. Following the main exposure, participants underwent a second baseline phase (i.e., a 180-second viewing of a static black cross to monitor the return of physiological responses to baseline levels). Afterward, they completed a post-experience questionnaire assessing their responses to the virtual experience. Finally, participants were offered the opportunity to take up to 10 printed flyers promoting the natural reserve, as a behavioral measure of promotion. The flyers were framed as materials to be shared with others, aligning the behavior with authentic promotional intention and encouraging word-of-mouth dissemination.

3.3. Instrumentation and measures

Participants' cortical, cardiac, and dermal responses were monitored throughout the experiment. Self-reported data were gathered both before and after the experience. Monitoring physiological parameters provides an objective and often non-intrusive means of evaluating user responses, and is widely endorsed in the assessment of VR experiences (Halbig & Latoschik, 2021; Mauri et al., 2024). Electroencephalographic (EEG) data were used to evaluate participants' attention, engagement, and pleasure during the experience, with a particular focus on the attention index (AI), pleasantness index (PI), and engagement index

Fig. 6. Experimental setup.

(EI). These EEG-derived indexes are based on spectral activity associated with attentional allocation, emotional valence, and cognitive engagement (Coelli et al., 2018; Vecchiato et al., 2011, 2012). Electrocardiographic and electrodermal activity (EDA) signals were analyzed to measure participants' arousal, understood as the physiological reactions that underlie states of alertness and emotional reactivity (Boucsein, 2012; Kreibig, 2010; Mehrabian & Russell, 1974). Electrocardiographic signals were processed to extract heart rate variability (HRV) features, including the mean interval between consecutive heartbeats (MeanRR), standard deviation of RR intervals (StdRR), and root mean square of successive differences between RR intervals (RMSSD). EDA signals were processed to extract the average value of the tonic component (tonic average). These arousal indicators are typically derived from responses governed by the sympathetic branch of the autonomic nervous system. Appendix A.1 presents the signal-processing procedure. Appendix A.2 reports the information flow and data confidentiality protocols.

Self-reported measures included the following constructs, assessed using pre-validated scales: ITC-Sense of Presence Inventory (Lessiter et al., 2001), willingness-to-travel (Tigre Moura et al., 2015), and engagement with the tourist destination (Kumar & Pansari, 2016; Loureiro & Sarmento, 2019). In addition, an ad-hoc item was included to serve as an indicator of the realism of the VR content (i.e., "How realistic was the environment shown?" assessed on a 7-point Likert scale). Participants also answered background questions regarding their prior VR experience, and rated their perceived level of technological expertise on a 6-point Likert scale ("In general, how would you rate your technology-related skills, from terrible to excellent?"), and their technology readiness ("Technology plays an important role in my daily activities").

Finally, a behavioral task was carried out to assess the promotion of the destination, following Chirico et al.'s (2023) method. After the VR experience, participants were given the option to take flyers that promoted the natural reserve depicted in the simulation and that were intended for distribution to others. Fig. 7 shows an example of the flyer.

Fig. 7. Promotional flyer supporting the promotion and preservation of the Fondo Toce Nature Reserve.

4. Results

Of the 58 participants initially recruited, one withdrew before completing the VR experience and was excluded from the subsequent analyses. Of the final sample, 34 participants completed the 360-VR experience and 23 the FD-VR experience. A manipulation check confirmed that the two conditions elicited different levels of perceived realism. The results showed an anecdotal effect for the two conditions (BF01 = 0.006, err. = $2.14e^{-8}$), with participants reporting higher perceived realism under the 360-VR condition (M = 4.75, SD = 1.34) than under the FD-VR condition (M = 3.35, SD = 1.11).

To test H_1, we examined the physiological responses induced by each VR condition by comparing participants' baseline measurements with those recorded during the VR experiences. This preliminary within-subject analysis served as a validation step within the stimulus–organism–response framework, verifying whether VR exposure elicited measurable physiological activation before examining differences between the VR formats. This within-subject analysis also aimed to identify which physiological indicators were most responsive to the cognitive and emotional changes elicited by the VR content. Differences were assessed using non-parametric two-tailed Wilcoxon signed-rank tests. Significant differences ($p < 0.05$) were found for several neurophysiological responses, such as AI, EI, and tonic average. On the other hand, among the HRV features, only stdRR showed sensitivity to the level of realism. HRV tends to exhibit slower responses than EDA and EEG signals, explaining why most features extracted from this signal did not differ significantly between the baseline and the VR experience. Overall, the indices exhibiting significant variations suggest higher sympathetic activation (increased tonic average) or cognitive engagement (increased AI and EI) during the VR experience, compared to the baseline period (see Table 1, within-subject analysis).

Next, we performed a between-subjects statistical analysis to investigate whether participants exhibited different physiological responses depending on the experimental treatment. To test hypotheses H_2a–d, we conducted one-tailed Wilcoxon rank-sum tests tailored to each hypothesis. H_2a was tested by considering the alternative hypotheses: $X_{FD\text{-}VR} > X_{360\text{-}VR}$, with X = tonic average; $X_{FD\text{-}VR} < X_{360\text{-}VR}$, with X representing

Table 1
Descriptive statistics of the physiological data (median ± inter-quartile range).

	Within-subject analysis		Between-subjects analysis	
	Baseline	VR experience (FD-VR or 360-VR)	FD-VR	360-VR
Tonic average [μS]	2.569 ± 1.957	2.740 ± 2.667	0.324 ± 0.863	0.211 ± 0.589
Attention index [a.u.]	1.341 ± 0.672	1.606 ± 0.857	0.104 ± 0.407	0.077 ± 0.823
Pleasantness index [a.u]	−0.033 ± 0.239	−0.013 ± 0.333	0.028 ± 0.128	0.019 ± 0.174
Engagement index [a.u.]	0.826 ± 0.644	1.226 ± 0.826	0.505 ± 1.098	0.403 ± 0.605
MeanRR [s]	0.794 ± 0.180	0.827 ± 0.148	0.014 ± 0.078	0.008 ± 0.057
StdRR [s]	0.049 ± 0.023	0.060 ± 0.026	0.007 ± 0.018	0.006 ± 0.020
RMSSD [s]	0.037 ± 0.017	0.038 ± 0.021	0.005 ± 0.013	0.004 ± 0.015

Note. Values related to the between-subjects analysis are reported as differences between the VR experience and the second baseline of the protocol. The tonic average was extracted from the electrodermal activity signal and is reported in microsiemens. Attention, pleasantness, and engagement indexes were extracted from the electroencephalographic signal and are reported in arbitrary units. MeanRR, StdRR, and RMSSD were extracted from the electrocardiographic signal as heart rate variability measures and are reported in seconds.

the heart rate variability features (MeanRR, StdRR, or RMSSD). Increased tonic average, as well as decreased MeanRR, StdRR, and RMSSD, are typically interpreted as markers of increased arousal (Colomer Granero et al., 2016; Mohammadpoor Faskhodi et al., 2023). H_2b and H_2c were evaluated through the alternative hypothesis $X_{FD\text{-}VR} > X_{360\text{-}VR}$, with X = AI or EI, respectively. These indices tend to rise with engaging content (Coelli et al., 2018; Vecchiato et al., 2012). H_2d was assessed through the alternative hypothesis $PI_{FD\text{-}VR} < PI_{360\text{-}VR}$ because increased PI is associated with higher alpha power in the right hemisphere of the brain than in the left hemisphere, indicating a greater sense of pleasantness (Vecchiato et al., 2012; Zhao et al., 2018). We conducted all tests on baseline-corrected values to account for individual variability in resting physiological states and enhance reliability. Thus, we subtracted the second baseline measurements from those recorded during the VR experiences. Positive baseline-subtracted values reflect an increase in the physiological index during the VR experience, whereas negative values indicate a decrease in it. Table 2 summarizes the results of the statistical analysis.

Some data points were excluded from the analysis because of excessive noise or artifacts. The final number of valid cases for each physiological signal is indicated accordingly. The primary sources of noise were participants' movements and interactions between the EEG electrodes and the head-mounted display straps. Following preprocessing, the data were deemed clean for approximately 86% of EDA recordings, 82% of EEG recordings, and 89% of electrocardiographic recordings. Among all tested variables, only tonic EDA showed a significant difference between the conditions ($p < 0.05$). The FD-VR condition elicited significantly higher tonic electrodermal activity than the 360-VR condition. Elevated tonic EDA is a marker of increased sympathetic arousal and emotional involvement; therefore, this finding suggests that the FD-VR experience triggered a more intense physiological response. This finding supports the hypothesis that FD-VR, despite its lower realism, can create a more stimulating and arousing user experience because of its higher perceptual load.

The absence of significant differences in the other physiological indices in the between-subjects analysis may be attributed to several factors. One possibility is that the laces securing the VR headset, combined with participants' natural head movements while exploring the virtual environments, may have introduced motion artifacts. Indeed, measures of EEG activity spatial distribution, including the global field power-based features we considered (AI and PI), can be sensitive to such noise. By contrast, the time-domain HRV measures used in this study may not have captured differences between the VR conditions because of their generally lower sensitivity to cognitive tasks in such short time frames. Both FD-VR and 360-VR may have produced similar short-term effects on the parasympathetic nervous system, resulting in comparable HRV outcomes.

Next, we conducted a series of Wilcoxon rank-sum and independent sample *t*-tests to compare differences between the experimental treatments and test the remaining self-report and behavioral hypotheses. Bayesian factors were computed because some data did not meet normality assumptions. All analyses were performed using Jamovi (v. 2.2.5.0). The results show that the 360-VR scenario is characterized by significantly higher ecological validity (BF01 = 0.468, err. = 0.008). By contrast, the FD-VR condition yielded higher levels of engagement (BF01 = 1.892, err. = 0.008), perceived sense of physical space (BF01 = 1.399, err. = 0.008), and negative effects (BF01 = 0.691, err. = 0.008). Regarding engagement with the tourist destination, participants in the FD-VR experience reported significantly higher purchases/visits (BF01 = 0.164, err. = $5.234e^{-7}$), referrals (BF01 = 0.106, err. = $4.23e^{-7}$), destination influence (BF01 = 0.867, err. = 0.008), and willingness to travel to the destination (BF01 = 0.118, err. = $3.68e^{-7}$). However, no significant difference was found between the groups regarding knowledge sharing. Table 3 presents a summary of the results. Lastly, the promotion of the destination and its preservation, measured by the number of flyers collected by the participant at the end of the session, did not display significant differences between treatments ($\chi2$ (1, N = 57) = 0.911, p = 0.340).

Table 2
Results of the within-subject and between-subjects statistical analyses conducted on the physiological data.

Tool	Indexes	Subjects analyzed	Within-subject (baseline vs. VR experience)	Between-subjects (FD-VR vs. 360-VR experience)
EDA	Tonic average	49 (21 FD-VR; 28 360-VR)	Significant	Significant
EEG	Attention index Engagement index Pleasantness index	47 (23 FD-VR; 24 360-VR)	Significant for attention index and pleasantness index	Not significant
HRV	meanRR stdRR RMSSD	51 (21 FD-VR; 30 360-VR)	Significant for stdRR	Not significant

5. Discussion

Tourism consumption enhances individuals' well-being (Chen & Petrick, 2013) by offering opportunities to escape daily routines and alleviate stress (Hobson & Dietrich, 1995; McLean et al., 2023; Sonnentag & Fritz, 2007; Su et al., 2020). Engaging in enjoyable activities, such as exploring natural landscapes, may induce psychological detachment (Sonnentag & Fritz, 2007), enabling visitors to experience the restorative benefits associated with travel. This study explores the affective, cognitive, and behavioral responses triggered by two types of virtual simulations of a natural tourist destination, each presenting a different level of realism. Physiological measures of arousal, attention, and engagement showed significant differences, confirming that the VR experiences elicited measurable psychophysiological activation. Hence, H_1 was confirmed. This result suggests that VR experiences are strongly linked to affective responses (Kim et al., 2020), extending evidence from prior studies (Mauri et al., 2024) to the visitor journey context. The result underscores the potential of immersive technologies to enrich the pre-visit phase (de Lurdes Calisto & Sarkar, 2024; Hoyer et al., 2020). By leveraging anticipation and promoting engagement, VR contributes to consumer well-being through enjoyable tourism experiences. Nevertheless, the study was conducted in a controlled laboratory setting, which may not fully capture the contextual dynamics and well-being-related aspects characterizing real-world tourism experiences. Although our experimental design controlled for participants' lack of familiarity with the tourist destination selected for the study, the pre-visit phase targeted by VR applications is not always temporally distinct and may overlap with on-site use. For example, visitors may continue engaging in pre-visit activities during their trip, such as exploring virtual previews of specific attractions. Therefore, VR-mediated interactions in the pre-visit phase may anticipate, complement, or even extend the on-site experience (Buhalis et al 2023; Loureiro et al, 2020).

Furthermore, our results reveal that the realism of the VR experience elicited differential responses in users. FD-VR simulations convey excitement (Slater et al., 2009), resulting in greater arousal than 360-VR experiences, supporting H_2a. This response was not observed in other physiological patterns; thus, H_2b, H_2c, and H_2d were not supported. FD-VR did not elicit stronger physiological responses related to attention and engagement than 360-VR. One possible explanation is that the heightened arousal induced by the perceptual load of FD-VR may interfere with users' attention, particularly when visitors feel stimulated by the immersive virtual environment (Leung et al., 2020). In such cases, high arousal may fragment attentional resources. Prior research supports this inverse relationship, showing that autonomic arousal can

Table 3
Means and standard deviations of self-report measures.

		Sense of presence: Engagement	Sense of physical space	Ecological validity	Negative effects	Willingness to travel	Engagement with the tourist place: Knowledge sharing	Purchases/ visits	Referrals	Destination influence
Treatment	360-VR	3.25 (0.62)	2.56 (0.78)	3.34 (0.87)	2.05 (0.66)	3.19 (1.28)	4.13 (1.43)	4.17 (1.16)	3.57 (1.58)	3.54 (1.34)
	FD-VR	3.47 (0.62)	2.88 (0.75)	2.78 (0.97)	2.46 (0.86)	4.05 (1.36)	4.03 (1.38)	5.08 (1.11)	4.76 (1.25)	4.25 (1.45)
Between-subjects comparison		Significant	Significant	Significant	Significant	Significant	Not significant	Significant	Significant	Significant

hamper attention during cognitively demanding tasks (Chee et al., 2024). Moreover, complex virtual environments characterized by lower realism and computer-generated visual aesthetics may contribute to fatigue, which, in turn, reduces users' engagement. In other words, FD-VR may be more intense, but not more engaging at a physiological level because of overstimulation. Nevertheless, FD-VR did not lead to lower levels of pleasure. This outcome could be attributed to the enhanced sense of presence fostered by fully digital environments, leading to positive emotions (Cheng & Huang, 2022) and affecting subjective well-being (Kim & Hall, 2019). These positive emotional responses may help counterbalance the potentially negative effects of overstimulation, often associated with FD-VR experiences.

In terms of psychological responses, FD-VR led to greater engagement and a stronger sense of physical space, reinforcing its ability to make users feel present within the environment. These findings support H_3 and H_4. However, FD-VR also produced more pronounced negative effects, confirming H_6. Cybersickness and perceptual load often emerge in complex virtual environments, such as FD-VR (LaViola, 2000). Furthermore, the lower ecological validity of FD-VR may generate a dissonant experience, contributing to a sense of unease and discomfort (Stein & Ohler, 2017) and further intensifying the negative aspects of the experience. The greater immersiveness and sense of presence may amplify such negative responses, provoking anxiety or stress. These effects may extend beyond the immediate experience and potentially lead to the long-term avoidance of VR (Han et al., 2022; Lavoie et al., 2021). By contrast, 360-VR demonstrated higher ecological validity than FD-VR, supporting H_5. The use of pre-recorded real-world environments in 360-VR enables it to convey more authentic and lifelike experiences, generating trust in visitors. This is a critical outcome, especially in the pre-visit phase, when visitors are forming initial impressions and expectations.

Regarding user responses, FD-VR experiences elicited a greater intention to revisit the destination, confirming H_7. This result suggests that highly immersive content enhances both user engagement with the destination and the desire to travel (Kang et al., 2021; Tussyadiah et al., 2018). However, knowledge sharing did not vary between the scenarios, rejecting H_8. One possible explanation is that although 360-VR may feel more authentic, it remains a virtual preview and may not evoke the emotional connection or sense of accountability typically driving information-sharing behaviors. Prior research shows that psychological, social, and political empowerment strongly influence support for tourism (Boley et al., 2014). These mechanisms tend to emerge from highly engaging encounters. It is also possible that knowledge-sharing intentions depend more on users' pre-existing motivations and social norms than on the realism of the VR environment.

Moreover, the FD-VR scenario yielded higher levels of consumer satisfaction about the visit, referral intent, and willingness to engage in word-of-mouth referrals, confirming H_9, H_{10}, and H_{11}, respectively. These results suggest that VR experiences that evoke strong emotional responses, such as excitement, boost engagement with the destination and motivate users to recommend it to others (Kang et al. 2021; Rafi et al., 2024; Tussyadiah et al., 2018). However, FD-VR did not induce a greater willingness to engage in the promotion and preservation of the natural reserve, rejecting H_{12}. Although the literature shows the relevance of affect in pro-environmental behaviors (Brosch, 2021), recent studies have reported diverging results, indicating that people who experience the effects of climate change via VR immersive technologies may be induced to action, but this may not be a direct consequence of the affective experience elicited (Meijers et al., 2023). Thus, the affective responses generated by FD-VR, although impactful, may be insufficient to trigger actual pro-environmental behaviors. Moreover, such behaviors often depend on either external incentives or a strong sense of moral obligation (Steg & Vlek, 2009; Van der Werff et al., 2013). Demographics, external factors (economic or cultural ones), and internal factors, from awareness to values and priorities, have been shown to influence—positively or negatively—pro-environmental behaviors (Kollmuss & Agyeman, 2002). Altogether, these issues suggest that the affective stimulation provided by FD-VR, while meaningful, may be insufficient to overcome the individual determinants that promote pro-environmental commitment, helping explain why the hypothesized effect did not arise. A further explanation relates to the lower perceived realism associated with fully digital VR experiences, which may have undermined the perceived authenticity and urgency of the environmental message, reducing users' willingness to act.

Overall, our findings help reconcile the divergent results in the literature. Although some studies have reported stronger psychophysiological and behavioral responses driven by content realism (Kisker et al., 2021; Tian et al., 2021), others have found that the overall experience and resulting behaviors remain largely unaffected (Weber et al., 2021; van Gisbergen et al., 2019). Our results suggest that two distinct mechanisms are at play. On one hand, perceived realism enhances the trustworthiness of the destination, although this does not necessarily lead to a greater willingness to contribute to its preservation. On the other hand, highly immersive and engaging digital experiences, characterized by a heightened sense of presence and emotional arousal, strongly influence intentions to travel and foster socially driven behaviors, such as recommendations. Our findings should also be interpreted in light of how immersive technologies are selected and implemented within tourism contexts. A company may choose between 360-VR and FD-VR depending on the specific experiential objectives. Firms may prefer 360-VR when the goal is to offer realistic, easily accessible previews that closely mirror the physical destination. By contrast, fully digital VR is better suited to creating emotionally rich simulations. On the consumer side, if given the opportunity, visitors may progressively move from familiar, low-effort formats toward immersive technologies as their comfort level and experiential needs evolve. This adoption trajectory is in line with technology acceptance research, showing that perceived ease of use shapes users' willingness to adopt new technologies over time (Sinha et al., 2025; Teng et al, 2025).

5.1. Theoretical contributions

The study contributes to the growing body of research on visitor experience with VR by uncovering the processes leading to behavioral intentions during the pre-visit phase. Although prior work has shown that VR can influence tourism-related decision-making (Loureiro et al., 2020; Tussyadiah et al., 2018), the cognitive and affective mechanisms underlying these effects remain insufficiently understood. Our findings confirm that VR tourism experiences influence consumers' physiological and psychological responses, contributing to the theoretical discourse on virtual engagement (Jung & Tom Dieck, 2017). In particular, we show that physiological arousal and subjective presence jointly shape users' evaluations and intentions in VR environments, complementing emerging research on consumer well-being in digital settings. Also, this study addresses inconsistencies in the literature regarding the role of VR realism in eliciting emotional responses and behavior (Guttentag, 2010; Wei et al., 2019). Some scholars argue that FD-VR, with its more stylized and simulation-like features, evokes stronger emotional responses that enhance user engagement with a destination (Kang et al. 2021; Tussyadiah et al., 2018). Others contend that 360-VR, by closely mirroring real-world environments, evokes more authentic emotions, which translate into booking intentions and immediate behavioral responses (Cheng et al., 2022). Based on the stimulus–organism–response framework, our findings extend theory by demonstrating for the first time that realism produces differentiated organismic responses across multiple presence-related dimensions. Varying degrees of realism differentially influence the engagement, spatial presence, ecological validity, and negative effects elicited by VR. This finding implies that the lower realism of FD-VR can maximize engagement and spatial presence through its game-like qualities, whereas the high visual realism of 360-VR enhances ecological validity without necessarily increasing engagement. These results indicate that realism involves systematic trade-offs: FD-VR enhances engagement and spatial presence but also induces more discomfort, whereas 360-VR increases ecological validity but inconsistently affects behavioral intentions.

Furthermore, this study explores consumer responses to VR by employing neurophysiological measures to capture implicit reactions that cannot be assessed through self-reports alone. Such unconscious responses are particularly relevant in multisensory and immersive environments, such as those created by VR technologies (Kakaria et al., 2023). They can mitigate the cognitive biases (e.g., social desirability and memory distortion) and shortcomings of self-related assessments (MacKenzie & Podsakoff, 2012), offering a more accurate representation of reactions to VR experiences (Huang & Liao, 2017). Thus, we provide a methodological contribution to the field, as prior studies mainly relied on self-reported data. Furthermore, our study proves the interplay among neurophysiological, psychological, and behavioral responses in VR experiences with different levels of realism, opening the way to improved methodologies for evaluating virtual experiences.

5.2. Managerial implications

Overall, tourism consumption is associated with mental and physical well-being. VR offers a wide range of multisensory experiences along the visitor journey, enabling previews of the destination and boosting visitors' involvement with the actual offering. However, different VR formats must be aligned with the objectives of tourism organizations to leverage the potential of this technology. The realistic 360-VR may increase consumer confidence, reduce uncertainty in selecting a destination, and enhance the brand image of and trust in the company. An improved alignment between expectations and reality may lead to reduced post-purchase regret and an enjoyable and fulfilling travel experience. Hence, 360-VR is well-suited for upper-funnel marketing objectives, such as raising awareness and building knowledge. Integrating realistic VR previews into booking platforms or destination websites can support consumers in their early-stage evaluations.

On the other hand, FD-VR generates a stronger sense of presence and emotional intensity, leading to stronger booking intentions. By fostering shared enthusiasm and social connection, FD-VR becomes a persuasive tool for middle- and lower-funnel marketing. Marketers may, for instance, leverage this format in community-based platforms, where users can share recommendations about destinations. Engaging influencers and enabling user-generated content may motivate consumer engagement with the destination and enhance online word-of-mouth recommendations and value-added feedback in a co-creative effort. Integrating a smooth purchase path within VR, such as direct links to the booking platform, may help convert such interest into purchases.

Nonetheless, FD-VR is not without limitations; its intensity may lead to negative outcomes, such as motion sickness or perceptual load, which may compromise user satisfaction. Repeated negative experiences may even foster resistance toward VR technology, undermining its adoption. Therefore, attention must be given to usability and personalization: reducing sensory and motion mismatches (Keshavarz et al., 2011; LaViola, 2000), designing intuitive user interfaces, and tailoring navigation to individual profiles (Chardonnet et al., 2021) are crucial functional enhancements. Moreover, user training through tutorials and walkthroughs can be helpful. Personalizing the interaction (e.g., movement speed or perspective adjustments) can further accommodate individual preferences. Real-time detection of discomfort indicators, such as head movements, may also enable adaptive responses within the VR environment, enhancing comfort and overall satisfaction. Thus, a user-centric design is crucial for evoking positive experiences and assuring consumers' well-being. Blending experiences in FD-VR with 360-VR may help streamline the visitor journey, enabling brands to provide their customers with unique experiences and guiding them along the marketing funnel to purchase (Jayawardena et al., 2023). Beyond supporting transactional and relational goals, this approach may achieve broader objectives, such as fostering long-term consumer well-being through emotionally resonant experiences.

6. Limitations and future research

The relationship among stimuli, organism, and responses is unlikely to remain fixed with the fast-paced shifts characterizing the tourism industry, such as growing sustainability demands, post-pandemic shifts in travel behavior, and ongoing technological innovation. Therefore, continuous research is essential for understanding how evolving technological stimuli and changing consumer characteristics shape visitors' psychological and behavioral responses. Technological advancements continue to expand the possibilities of virtual experiences. Although FD-VR and 360-VR engage visual and auditory senses, they remain limited in replicating other sensory dimensions of real-world travel, such as touch or smell. Integrating haptic feedback or olfactory cues into virtual experiences could offer a more holistic sense of presence and boost emotional engagement with destinations. Thus, future research should explore the impact of these multisensory features on users' psychological responses and travel-related behaviors.

Cultural and destination-specific factors may also shape how consumers respond to VR. Cultural dimensions, such as power distance or uncertainty avoidance, can influence openness to innovation and technology adoption. For example, individuals from cultures with low power distance and low uncertainty avoidance may be more receptive to VR tourism experiences (Singh, 2006). The present study was conducted in Italy, a country that generally scores moderately on both dimensions. This fact may have influenced participants' expectations about VR experiences. The type of environment depicted also matters. Although the mechanisms identified in our study regarding the effects of realism may extend to a wide range of tourism settings and VR applications (de Lurdes Calisto & Sarkar, 2024), the specific responses may differ by destination typology. For instance, naturalistic sceneries may raise a stronger sense of presence than complex urban scenes, which may demand greater cognitive processing and trigger higher arousal (Valtchanov & Ellard, 2010). By contrast, cultural heritage sites often count on VR to enrich learning, authenticity perceptions, and destination image formation (Ch'Ng et al., 2020). Adventure experiences, such as VR simulations of hiking trails or extreme sport performances, may elicit higher arousal and thrill, shaping behavioral intentions through excitement. Jointly, these examples underscore how different VR tourism contexts may engage distinct motivational, cognitive, and affective routes. Thus, future studies could examine how diverse destination typologies influence consumer responses to technology-mediated experiences.

Third, although engagement and willingness to travel offer relevant insights into individuals' psychological responses and attitudinal intentions, the current study does not account for involvement, a possible antecedent to these outcomes (Havitz & Dimanche, 1990). Insufficient involvement, engagement, or intent may not lead to actual behavior. Thus, future studies should consider involvement to better understand the motivational drivers behind VR-induced responses. Furthermore, we did not collect information regarding participants' travel frequency or tourist profiles. Hence, future studies could examine whether prior travel habits or tourism involvement moderate users' responses to VR environments. In a similar vein, individual differences among consumers can influence how realism in VR is perceived and processed. For some users, high levels of realism may enhance presence, emotional response, and destination evaluation. However, others, particularly those unfamiliar with VR or less digitally literate, may experience discomfort because of sensory mismatches or perceptual load. Investigating these segment-specific reactions is crucial for designing inclusive, user-friendly experiences.

Fourth, although VR applications are analyzed in this context as shaping the pre-visit phase, the intentions formed during this stage may not necessarily translate into an actual visit, given potential constraints, such as financial limitations, competing destinations, or shifts in visitors' preferences. Therefore, future longitudinal studies should investigate how VR-mediated pre-visit interactions influence following travel behavior, and whether effects vary depending on the type of destination or the user's travel motivation. Such studies could provide a better understanding of the boundaries of the pre-visit stage within the broader customer journey.

We used the number of flyers collected as a behavioral measure of promotion, in line with Chirico et al. (2023). However, we did not control for specific aspects of the flyer's content or visual design, such as wording, imagery, or layout, a limitation that may have influenced participants' willingness to take them. Therefore, future studies should consider testing the effects of these design elements or employing alternative behavioral indicators. Finally, we acknowledge that the controlled laboratory setting and the limited sample size constrain the generalizability of the findings. Even though the laboratory environment ensured high internal validity and standardized exposure across participants, it may not fully reproduce the complexity of real-world tourism decision-making settings. Moreover, although our sample aligns with previous research combining neurophysiological measures and head-mounted displays in tourism contexts (Kakaria et al., 2023; Saffari et al., 2023) and is demographically consistent with comparable studies (Sanders et al., 2024), sample size remains a limitation, as is common in consumer neuroscience (Kansra et al., 2024). Moreover, the narrow age range of our participants (19–28) may introduce bias, as younger individuals typically show higher familiarity and comfort with immersive technologies. However, the growing availability of wearable technologies capable of gathering accurate physiological data outside laboratory settings (Knierim et al., 2021; Reali et al., 2022) offers promising prospects. These tools can allow researchers to conduct large-scale studies with a more diverse population. By addressing these avenues, future studies can deepen the mechanisms underpinning users' experiences with VR and support practitioners in delivering compelling experiences along the visitor journey.

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CRediT authorship contribution statement

Debora Bettiga: Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Marco Mandolfo:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization, Formal analysis. **Pierluigi Reali:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Eleonora Diletta Sarcinella:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

Appendix

A1. Physiological measures

During the experiment, participants were seated in a height-adjustable chair with armrests to ensure a consistent posture and minimize upper-body movement. A researcher continuously monitored the physiological signals throughout acquisition to ensure data quality. Cortical activity was recorded using 29 EEG channels at a sampling rate of 256 Hz with a clinical-grade device (SD LTM Express, Micromed, Italy). Electrodes were positioned according to the 10–10 system using a pre-cabled cap, and all impedances were maintained below 10 kΩ. EEG preprocessing was performed according to current state-of-the-art recommendations (Coelli et al., 2024), using the EEGLAB toolbox (MATLAB version 2023a). Following an initial bandpass filter (1–35 Hz, Hamming-windowed finite impulse response filter) to remove motion artefacts and general noise, the raw data were visually inspected. Muscular and ocular artefacts were then identified and removed using independent component analysis (Delorme & Makeig, 2004). To further reduce uncorrelated noise and enhance signal quality, a Common Average Reference was applied to the original EEG. Each participant's Individual Alpha Frequency (IAF) was determined from baseline physiological activity following Klimesch (1999). The EEG data were then bandpass filtered using a Kaiser window-based second-order filter to isolate spectral activity within the upper alpha band (IAF to IAF+2 Hz). Next, lower alpha band activity was extracted from channels Fpz, AF3, F3, AF4, F4, and Fz to compute AI. The upper alpha band, filtered in channels F3, AF3, F4, and AF4, was used to compute PI, as described by Vecchiato et al. (2012). Lastly, EI was calculated as the ratio of beta to alpha power, following Coelli et al. (2018).

Electrocardiographic (ECG) and electrodermal (EDA) signals were collected using a research-grade polygraph (ProComp Infiniti, Thought Technology, Canada) at sampling rates of 1024 Hz and 16 Hz, respectively. ECG electrodes were placed in a Lead I configuration, while EDA electrodes were attached to the index and middle fingers of the non-dominant hand. From these signals, we extracted indices correlated with the dimension of arousal (Mehrabian & Russell, 1974). Cardiac-related responses were extracted from the heart rate variability (HRV) signal, namely the beat-to-beat time series of inter-beat (or RR) intervals extracted from the ECG. From the HRV signal, we calculated the average (meanRR) and standard deviation (stdRR) of the inter-beat intervals and the Root Mean Square of Successive Differences (RMSSD), time-domain features that tend to be correlated with physiological arousal (Kreibig, 2010). For the EDA signal, we extracted the average value of the tonic component (Tonic average) through the Continuous Decomposition Analysis using the established Ledalab toolbox (Benedek & Kaernbach, 2010). This feature is commonly used to measure dermal-related responses and, specifically, changes in the skin's electrical conductance, which is a marker of sympathetic activity (Boucsein, 2012). EDA tonic activity was used as a direct indicator of sympathetic arousal, whereas HRV features extracted from ECG were used to assess autonomic regulation associated with emotional activation. In particular, lower values of MeanRR, StdRR, and RMSSD are commonly associated with increased physiological arousal.

A2. Information flow and data confidentiality

The study received approval from the Institutional Review Board of the Università Cattolica del Sacro Cuore (Milan, Italy), protocol number 65/24, ensuring compliance with guidelines for studies involving human participants. The experimental protocol was designed to uphold ethical standards in the handling of all personal, physiological, and behavioral data. All data were stored on encrypted, password-protected laboratory servers accessible only to authorized personnel. Personally identifiable information (e.g., name, surname, date and place of birth), collected solely for the legal validity of informed consent, was stored in a physically and digitally separate database from the one containing experimental data. To ensure anonymity, each participant was assigned a unique identification code used to link non-identifiable demographic data (i.e., age and gender) with physiological and behavioral measures, including cortical (EEG) and cardiac (ECG), and dermal (EDA) data. Researchers involved in neurophysiological data processing and analysis had no access to personal identifiers and worked exclusively with anonymized datasets.

Participants were fully informed, through an initial consent form, about the nature of the physiological data collected, how it would be used, and the measures taken to ensure their confidentiality. The consent protocol explicitly outlined participants' rights to withdraw at any time and provided contact information for data protection inquiries. All reported results are presented in aggregate form, with no individual-level data disclosed, thereby minimizing any risk of re-identification.

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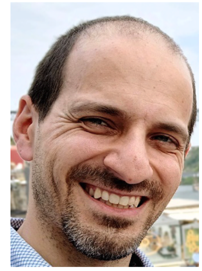

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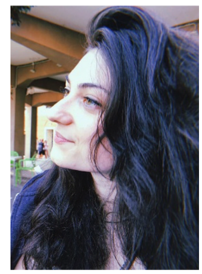

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