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Impact of immersive virtual reality on environmental mental imagery, climate risk perception and attitudes towards mitigation behaviors

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ABSTRACT

This paper aims to investigate the effect of immersive 360° VR video (vs. non-immersive) on environmental mental imagery, climate change risk perception and attitude towards climate change mitigation behaviors, incorporating climate skepticism as a moderator. A field experiment was conducted with 319 participants, using a between-subjects design to manipulate the level of immersion of a 360° video (immersive vs. non-immersive) illustrating the negative effects of climate change in Tunisia. The results show that immersive 360° VR video (vs. non immersive) increases significantly environmental mental imagery. They also reveal that environmental mental imagery positively influences climate change risk perception and attitude towards climate change mitigation behaviors, and that climate skepticism negatively moderates these relationships.

Keywords: immersive VR, environmental mental imagery, climate change risk perception, attitudes towards mitigation behaviors, climate skepticism

INTRODUCTION

Climate change represents a major challenge for humanity, with dramatic consequences on the environment (Thoma et al., 2023). Tunisia, like many countries around the Mediterranean, is facing an alarming rise in temperatures. Thermometers are hitting record highs every year, turning summers into intense heatwaves (Ben Said, 2024). These extreme temperatures have a direct impact on the daily lives of Tunisians, affecting health, agriculture and even tourism. Droughts are on the increase, threatening water resources and agricultural production, while heat waves increase the risk of forest fires and heat-related health problems (Ben Said, 2024). Climate change progressively makes it difficult to communicate its repercussions (Fauville, 2018; Sen et al., 2021). Community awareness is enhanced by personal accounts of direct experience and by the global visual communication of catastrophic weather events occurring in various countries (Dhunnoo et al., 2023; O'Neill & Smith, 2013). However, outside of these mega-events, communicating climate change can be complex (Fauville, 2018; Queiroz et al., 2018), as traditional methods, such as brochures and 2D images, do not always have the desired impact (Kleinlogel et al., 2023; Nisa et al., 2019). To meet this challenge, it is essential to raise awareness of the consequences of climate change. However, this task is proving difficult, as public awareness is often limited and its current level of concern does not reflect the magnitude and severity of the problem (Carmichael & Brulle, 2017). Indeed, previous studies show that many people still perceive climate change as a psychologically distant, abstract and non-urgent threat (Thoma et al., 2023; Van der Linden, 2015). Thus, psychological barriers, such as lack of immediacy, remoteness of impacts, time lag and uncertainty (Gifford, 2011), hinder individuals' engagement with environmental change and are often linked to a lack of vivid and concrete environmental mental imagery (Lee et al., 2018). Mental imagery is "a processing mode in which multisensory information is represented in a gestalt form in working memory" (MacInnis & Price, 1987). It makes abstract phenomena more tangible by eliciting vivid internal representations (Boomsma et al., 2016). For example, when an individual imagines their hometown submerged by rising waters, or a familiar forest reduced to ashes due to a fire, they are experiencing a form of environmental mental imagery. This process can activate emotions, reinforce the perception of risk, and encourage pro-environmental behavioral intentions (Sinclair et al., 2021; Zaleskiewicz et al., 2023). In addition, the ability to mentally

imagine the consequences of climate change in places that are known or geographically close, rather than in distant and anonymous places, is a key psychological lever for overcoming the abstraction of climate messages and triggering individual mobilization (Ahn et al., 2014; Nouri et al., 2025).

Although some studies have demonstrated the effectiveness of images in raising awareness of environmental issues and encouraging pro-environmental behavior, most of the work focuses on traditional forms of communication, such as texts or 2D video (Boomsma et al., 2016; O'Neill & Smith, 2013), which do not always have the desired impact (Kleinlogel et al., 2023). To the best of our knowledge, the impact of mental imagery generated by immersive virtual reality (VR) experiences remains understudied. This gap is particularly significant because visual representation, especially in an immersive setting, can make the consequences of climate change more tangible and engaging, thus influencing both risk perception and attitudes (Ahn et al., 2014). Indeed, VR allows users to experience environmental scenarios in a way that simulates reality, creating an immediate and personal connection with climate issues (Kleinlogel et al., 2023). For example, an immersive experience could immerse a user in an environment affected by climate-related disasters, such as droughts or rising sea levels. This can evoke strong emotions, which can prompt individuals to think about their own impact on the environment and the importance of mitigating the effects of climate change (Dhunnoo et al., 2023; Kleinlogel et al., 2023; Queiroz et al., 2018). In addition, these immersive VR experiences can facilitate the activation of mental imagery (Skard et al., 2021), a process by which individuals mentally visualize specific events or consequences related to climate change. This ability to visualize can foster climate change risk perception and encourage a more favorable attitude towards climate change mitigation behaviors.

However, although several studies have examined the effect of climate change skepticism (Akter et al., 2012; Chen, 2020; Engels et al., 2013; Leka & Furnham, 2024), to our knowledge, its impact in the context of immersive VR experiences has not yet been studied. Research on climate change skepticism has shown that public doubts about the consequences of this phenomenon strongly influence mitigation and adaptation behaviors (Akter et al., 2012; Engels et al., 2013). Skepticism is often described as a major barrier to behavior change and skeptical people are generally less likely to support mitigation measures (Akter et al., 2012; Chen, 2020). Therefore, it is very likely that the impact of environmental mental imagery, generated by immersive VR experiences, on climate risk perception and attitudes towards climate change mitigation behaviors is influenced by climate change skepticism.

Given these limitations, it is reasonable to suggest that the use of immersive VR to illustrate the negative consequences of climate change could enhance environmental mental imagery, which in turn should foster climate change risk perception and attitude towards climate change mitigation behaviors. Consequently, this study seeks to answer the following research questions:

RQ1 Does an immersive 360° video increase environmental mental imagery?

RQ2 What effect does environmental mental imagery have on climate risk perception and attitude towards climate change mitigation behaviors?

RQ3 To what extent does climate skepticism affect the effect of mental imagery on climate change risk perception and attitude towards climate change mitigation behaviors?

This article is organized as follows: the first part provides a review of the literature and presents the research hypotheses. Next, the methodology section describes in detail how the data was collected through an experimental study. The results are then presented, followed by a discussion of the findings. Finally, the study's contributions, limitations and future research directions are presented.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Virtual Reality and Climate Change

Marketing is about understanding and influencing consumer behavior, and its role becomes even more crucial in the context of climate change. In particular, social marketing strives to use marketing techniques to encourage behavior that benefits society and environment (Frechette et al., 2023). This type of marketing is emerging as an essential tool for promoting pro-environmental actions in response to current climate challenges (Rodriguez-Sanchez, 2023). Numerous researchers have focused on this area, identifying effective strategies for raising awareness among target audiences. For example, McKenzie-Mohr (2022) highlights behavioral change approaches inspired by social change theory, showing that specific interventions can bring about substantial changes in individual and collective behavior in response to climate change. This work highlights the fact that, when properly designed and applied, social marketing can play a decisive role in promoting action in favor of the environment and the fight against climate change. This work highlights the fact that, when properly designed and applied, social marketing can play a decisive role in promoting action in favor of the environment and mitigating climate change.

While traditional media can help to explain and illustrate environmental issues, immersive VR experiences simulating the consequences of climate change could have a more powerful psychological effect, raising both awareness and attitudes to the issue (Nouri et al., 2025). Over the last twenty years, research has made considerable progress in the use of VR to influence opinions, attitudes and, to a lesser extent, behaviors (Slater & Sanchez-Vives, 2016). Although its application in the field of environmental impact is still limited, several studies have explored its potential (Ahn et al., 2014; Gonçalves et al., 2022, Nouri et al., 2025; Raja & Carrico, 2021). For example, Raja and Carrico (2021) showed that most participants who had VR experience of ocean acidification perceived the problem as more psychologically tangible and experienced negative emotions towards it. This is due to the increased ability of researchers and media developers to design immersive 3D environments, enabling users to experience situations virtually as if they were real experiences (Gonçalves

et al., 2022). Immersive VR experiences, usually delivered through a head-mounted display (HMD), isolate the user from the outside world and occupy a large part of the user's field of vision, reinforcing the sense of presence in the virtual world (Thoma et al., 2023).

Unlike traditional computer screens, these headsets offer a direct, embodied experience of the consequences of climate change, bringing users psychologically closer to the problem than simply watching a video (Markowitz & Bailenson, 2021). In particular, immersive VR enables realistic visualization of the effects of climate change, which are often difficult to observe due to long time scales, influencing both cognitive and affective processing (Thoma et al., 2023). On a cognitive level, immersion facilitates the construction of a mental representation of the mechanisms of climate change and its consequences, thereby increasing awareness of environmental risks (Ahn et al., 2014; Thoma et al., 2023). On an affective level, it fosters a stronger emotional link with the environment, making climate issues more personal and concrete (Ahn et al., 2014; Akerlof et al., 2013). In contrast, in non-immersive virtual environments, participants can explore the content by manipulating devices such as a computer, Smartphone or tablet, moving the screen to navigate in the environment, offering a less immersive experience (Repetto et al., 2018). These promising results suggest that immersive VR simulations can provide an effective and engaging representation of the real impacts of climate change.

Effect of Immersive VR on Mental Imagery

Several researchers have pointed out that external imagery plays a crucial role in the way people understand real-world issues, by transforming abstract problems into something concrete and visually comprehensible, to which they can react (O'Neill & Smith, 2013). Smith and Joffe (2009) noted that 'visual information is likely to play a powerful role in positioning public conceptions of climate change'. Environmental mental imagery refers to the visual representations that a person associates with environmental changes (Boomsma et al., 2016). A large body of research in a variety of contexts has examined the use of VR as a promising technology, demonstrating that it enables individuals to develop vivid mental representations of the virtual world (Saunders et al., 2011; Skard et al., 2021; Tussyadiah et al., 2018). These dynamic mental images generated by VR offer users the opportunity to actively interact with their virtual environment, enhancing their sense of presence and engagement (Saunders et al., 2011). Furthermore, previous research has shown that consumers' mental imagery is enhanced by various stimuli and presentation formats (Bogicevic et al., 2019; Zhang et al., 2024). Among these formats, immersive VR stands out for its enhanced impact on cognitive processing, enabling individuals to fully immerse themselves in the represented experience and to mentally simulate interaction with objects or content within a specific context (Zhang et al., 2024). This ability of VR to stimulate imagination significantly improves the way consumer process information and plays a key role in facilitating behavioral responses (Jung et al., 2021). Bogicevic et al. (2019) argued that immersive VR experience elicits more vivid mental imagery. Fan et al. (2022) pointed out that immersive VR experiences enhance the sense of presence, thus increasing the quality of mental imagery. In the tourism domain, Skard et al. (2021) showed that an immersive VR experience engages consumers more in mental imagery processes than traditional formats. In addition, the study by Zhang et al. (2024) demonstrated that the presentation of a product using a VR headset (HMD) generates stronger mental imagery than that induced by a simple static image, in the context of retail sales. By transposing these results to the context of climate change, we anticipate that exposure to 360° immersive video increases participants' environmental mental imagery more than exposure to non-immersive video. Based on the previous literature, we propose the following hypothesis:

H1: The immersive VR video increases participants' environmental mental imagery more than the non-immersive VR video.

The Impact of Mental Imagery on Climate Change Risk Perception and Attitude Towards Climate Change Mitigation Behaviors

Some researchers have suggested that environmental imagery can play an important role in shaping beliefs about climate change, influencing attitudes and behaviors in particular (Boomsma et al., 2016; Karlsson et al., 2024; Maiella et al., 2020; Smith & Leiserowitz, 2012). However, psychological barriers such as the lack of a sense of urgency, the perception of the geographical and temporal remoteness of impacts, as well as uncertainty, often hinder individual engagement in pro-environmental actions (Gifford, 2011; Lorenzoni et al., 2007). These barriers are frequently associated with a lack of clear and concrete mental representations of the environmental situation (Lee et al., 2018). In cognitive psychology, mental images are known to facilitate the formation and regulation of behavioral goals, playing a central role in the orientation of actions (Connor et al., 2014). Thus, Leviston et al. (2014) showed that people expressing greater acceptance of climate change tend to possess more concrete environmental mental images, which strengthens their potential engagement in pro-environmental actions. Other studies have found a significant correlation between mental images and the formation of environmental goals, as well as self-reported changes in behaviors, such as energy and sustainability behaviors (Boomsma et al., 2016). This suggests that the integration of environmental impacts into vivid mental images could play a key role in triggering pro-environmental behaviors (Leiserowitz, 2006; Smith & Leiserowitz, 2012; Weber, 2006). Consequently, the creation of vivid environmental mental imagery could be crucial for stimulating reactions and actions that promote sustainable behaviors (Boomsma et al., 2016), by inducing greater psychological proximity (Maiella et al., 2020).

Mental imagery also appears to play a key role in helping individuals focus on places and events, whether real or imagined, which can make environmental information more personally relevant (Karlsson et al., 2024). Imagery has been proposed as one of the best predictors of climate change risk perception (Leiserowitz, 2006; Smith & Leiserowitz, 2012). A study in the field of health has shown that mental imagery is a key psychological mechanism for reinforcing engagement with the information presented (Sinclair et al., 2021). In this sense,

mentally visualized events can influence both future behaviors and the way experiences are perceived (Schacter et al., 2008). Furthermore, it has been suggested that mental imagery can trigger emotional and affective responses (Holmes et al., 2008; Karlsson et al., 2024; Renner et al., 2019). Chen and Wu (2023) pointed out that mental imagery reinforces the effectiveness of attitudes in favor of nature conservation.

H2: Environmental mental imagery positively influences climate change risk perception.

H3: Environmental mental imagery positively influences attitude towards climate change mitigation behaviors.

The Moderating Effect of Skepticism

Although many factors influence the climate, scientists agree that human activity is the main cause of warming (Chen, 2020). However, to our knowledge, the way in which climate skepticism interacts with other perceptions of climate change remains insufficiently studied. According to Rahmstorf (2005), there are three forms of climate skepticism: trend skepticism, which doubts the reality of climate change; attribution skepticism, which doubts human causes; and impact skepticism, which minimizes the potential consequences of climate change. Some individuals doubt the anthropogenic origin of climate change and attribute extreme weather events to natural events (Chen, 2020). Furthermore, these skeptics may doubt that certain recent environmental disasters are related to human-induced climate change, which contributes to their hesitancy to adopt pro-environmental behaviors (Lorenzoni et al., 2007). According to Hornsey et al. (2016), climate change interventions could have a significant impact on the pro-environmental motivation of skeptics. Skeptics are generally less inclined to adopt environmentally friendly practices. The propagation of climate skepticism tends to weaken people's willingness to take action to reduce negative environmental impacts (Kortenkamp & Moore, 2006). Research on climate change skepticism shows that persistent public skepticism about the causes and consequences of climate change negatively influences mitigation and adaptation behavior (Akter et al., 2012; Engels et al., 2013). Furthermore, climate change skeptics are less likely to support mitigation measures (Akter et al., 2012). Chen (2020) showed that climate change skepticism moderates the effect of individual's sustainability self-identity on purchase intention towards sustainability-labeled coffee. Consequently, it is possible that climate change skepticism may negatively moderate the effect of mental imagery on the perception of climate change risks and attitudes towards climate change mitigation behaviors. Therefore, the following hypothesis is formulated:

H4: Climate change skepticism negatively moderates the effect of environmental mental imagery on:

a) climate change risk perception and
b) attitude towards climate change mitigation behaviors.

Given the above hypotheses' development, this paper proposed a conceptual model presented in **Figure 1**.

METHODOLOGY

Design and Procedure

This study aimed to investigate the impact of a 360° immersive video (vs. non-immersive) on environmental mental imagery, climate risk perception and attitude towards climate change mitigation behaviors. To this end, a 360° video illustrating the negative effects of climate change in Tunisia was used. This video, designed specifically to illustrate the tangible consequences of climate change in Tunisian context, plunges participants into realistic, hard-hitting scenes where the environmental impact is directly visible. The video highlighted a number of scenarios relating to the impact of global warming in Tunisia, such as the desertification of agricultural land, drought and the reduction of water resources. For example, participants could virtually 'find themselves' in rural areas that were once fertile but are now affected by desertification. These scenes were intended to make concrete the environmental threats which, although global, have specific local effects in Tunisia. The aim of the video was to enable participants to feel the consequences of global warming as if they were witnessing it directly.

To achieve the objectives of this study, an experiment was carried out in a shopping centre in Tunisia (Mall), a dynamic and realistic environment that increased the external validity of the experiment, as the participants were not in a controlled laboratory setting, but in a public place. The experiment was based on an inter-subject design, manipulating the degree of immersion of the 360° video: each participant was assigned to

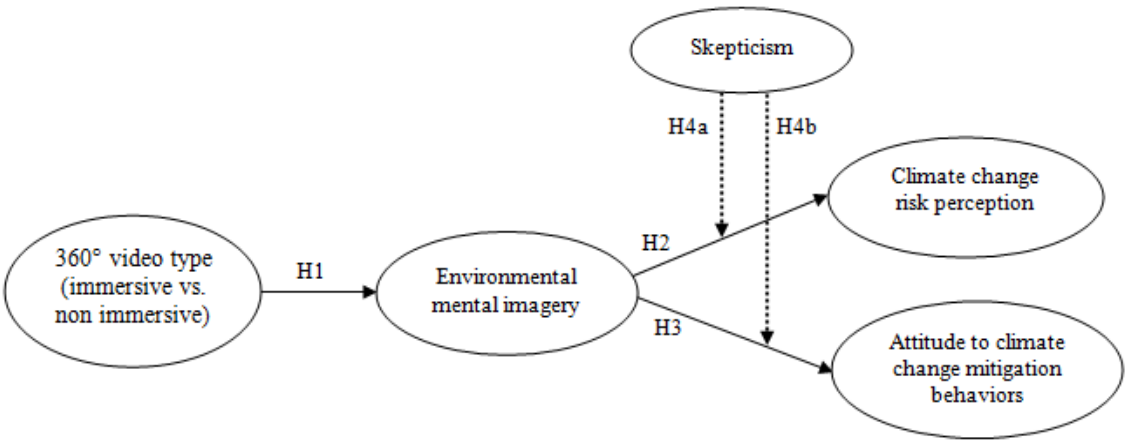

Figure 1. Conceptual model (Source: Authors' own elaboration)

a single experimental condition (immersive or non-immersive). Upon acceptance, participants were welcomed and informed that their responses would remain confidential and anonymous, thus guaranteeing the validity of the data collection. Preventive measures were also put in place to prepare participants for the immersive experience and reduce potential negative effects of using the VR HMD, such as motion sickness, including a pre-experimental briefing and the use of a swivel chair. Before viewing the 360° video (immersive or non-immersive), participants first assessed their level of environmental mental imagery. To ensure random assignment to the two groups, a simple randomization method was applied: a coin flipping (heads for the immersive condition and tails for the non-immersive condition), guaranteeing an equal probability for each individual to be assigned to one of the conditions, thus eliminating selection bias and enabling a reliable comparison of results between the groups. Although simple, this procedure proved crucial in maintaining the internal validity of the study. Participants assigned to the immersive condition used a VR HMD (Head-Mounted Display), while those assigned to the non-immersive condition viewed the video on a Smartphone. The HMD provided total immersion by submerging the participant in the virtual environment in which he or she was isolated from the real environment, while the Smartphone, although it allowed a 360° video to be viewed, did not offer the same level of sensory immersion, as the user remained aware of his or her physical environment. After viewing the 360° video, participants were again asked to assess their level of environmental mental imagery and to indicate their climate change risk perception, their attitude towards climate change mitigation behaviors and their climate change skepticism. Finally, they were thanked for their participation and informed of the possibility of receiving the results of the study if they wished after the end of it.

Measures

The scales used to measure the variables studied were adapted from previous literature in the context of climate change. Environmental mental imagery was measured using four items developed by Kavanagh et al. (2009) and adapted by Boomsma et al. (2016) ranging from 1 “Not at all” to 7 “Extremely /Constantly”. Climate change risk perception was assessed with six items extent to which respondents perceive climate change to be a risk to their own health, financial status, and environmental welfare (3 items), and to public health, the economy and environmental integrity within their region (3 items). These items were drawn from the scale of Kellstedt et al. (2008) and ranged from 1 "strongly disagree/no risk" to 7 "strongly agree/high risk". Attitude towards climate change mitigation behaviors were assessed using 11 items developed by Tobler et al. (2012) and adapted by Shi et al. (2015) and Hurst Loo and Walker (2023). Participants rated their willingness to engage in these behaviors on a 7-point scale ranged from 1 “I am not willing at all” to 7 “I am already doing this”. Lastly, based on the classification of climate skepticism proposed by Rahmstorf (2005): trend-attribution-impact, climate change skepticism was measured using four items developed by Poortinga et al. (2011) and adapted by Chen (2020). These items were operationalized using a 7-point Likert scale (1 “strongly disagree”, 7 “strongly agree”).

Table 1. Respondents profile

		N	Precentage
Gender	Men	148	46.4
	Woman	171	53.6
Education level	Primary	74	23.2
	Secondary	101	31.7
	University	144	45.1
Martial status	Single	125	93.2
	Married	109	34.1
	Divorced	58	18.2
	Widowed	27	8.5
		Mean	Range
Age		31.23	19-62 years

RESULTS

Demographic Profile

A total of 321 participants were recruited for the study. Although precautions were put in place to minimize adverse effects, in line with recommendations from previous research, some participants still experienced symptoms of motion sickness. These precautions included a pre-experimental briefing to prepare subjects for the immersive experience, and the use of a swivel chair to allow participants to adjust their field of vision and reduce discomfort. Despite these precautions, 5 participants in the immersive condition had to abandon the experiment because of persistent symptoms of motion sickness. This drop-out rate, representing less than 2% of the total sample, remains low and does not compromise the statistical validity or alter the results. The final sample thus comprised 319 people (As shown in **Table 1**), with slightly more women (53.6%) than men (46.4%). In terms of education, 45.1% have a university-level education, 31.7% have secondary-level education, and 23.2% have a primary level education. Marital status indicates that the majority are single (39.2%), followed by married individuals (34.1%), with smaller percentages of divorced (18.2%) and widowed participants (8.5%). The average age in the sample is 31.23 years, ranging from 19 to 62 years.

Manipulation Check

Manipulation was checked using a single item adapted from Barnidge et al. (2022) ("How do you feel the video was immersive?") ranging from 1 = “Not very immersive” to 7 = “Very immersive”. An independent samples t-test was performed, revealing a significant difference between the two groups in the perceived level of immersion ($t = -9.445$, $p < 0.001$). Participants who used HMD headset rated the video as more immersive than those that used only Smartphone $M_{\text{immersive}} = 4.64$ vs. $M_{\text{non immersive}} = 3.36$, demonstrating a significant difference in perceived immersion between the two conditions.

Furthermore, to ensure that this difference was indeed due to the manipulation of the immersion level of the 360° video and not to other variables such as demographic characteristics, control measures were performed. The results revealed no significant difference between the two groups regarding gender ($X^2 = 2.004$; $p = 0.157$), age ($t = 0.247$; $p = 0.805$), education level ($t = -1.028$; $p = 0.305$) and marital status ($t =$

Table 2. Exploratory and confirmatory factor analyses

Item	Factor loadings	Cronbach alpha	CR	AVE
Environmental mental imagery		0.924	0.938	0.790
EMI1	0.884			
EMI2	0.892			
EMI3	0.889			
EMI4	0.891			
Climate change risk perception		0.934	0.940	0.724
CCRP1	0.854			
CCRP2	0.842			
CCRP3	0.848			
CCRP4	0.851			
CCRP5	0.856			
CCRP6	0.855			
Attitudes to climate change mitigation behaviors		0.946	0.947	0.621
ACCMB1	0.794			
ACCMB2	0.791			
ACCMB3	0.796			
ACCMB4	0.789			
ACCMB5	0.787			
ACCMB6	0.782			
ACCMB7	0.793			
ACCMB8	0.788			
ACCMB9	0.785			
ACCMB10	0.780			
ACCMB11	0.781			
Skepticism		0.935	0.936	0.786
Skep1	0.888			
Skep2	0.883			
Skep3	0.886			
Skep4	0.889			

0.534; p = 0.594). Consequently, no covariates were integrated into the hypothesis tests.

Reliability and Validity

To ensure the methodological rigor of the study, both validity and reliability tests were performed. Common method bias (CMB) was initially evaluated using Harman's single-factor test, revealing that a single factor accounted for only 39.56% of the total variance, which is well below the suggested 50% threshold (Podsakoff et al., 2003). Furthermore, results from the exploratory and confirmatory factor analyses (see **Table 2**) indicated that Cronbach's alpha and composite reliability values were all above the 0.60 (Hair Jr et al., 2010), with average variance extracted (AVE) values surpassing the recommended minimum of 0.50 (Fornell & Larcker, 1981). Thus, all scales were deemed both reliable and valid.

Hypotheses Testing

In order to assess the impact of immersive VR video (versus non-immersive video) on environmental mental imagery, a mixed model ANOVA analysis was performed. This analysis included the following predictors:

1. Type of 360° video (non-immersive vs. immersive, coded 0 and 1 respectively),
2. Time (before and after exposure) and
3. Their interaction.

The type of 360° video was included as a between-subjects factor, while time was included as a within-subjects factor. This model makes it possible to examine whether immersive video increases environmental mental imagery more than non-immersive video.

The results obtained (**Table 3**) indicated a significant effect of video type: the level of environmental mental imagery was higher for the immersive 360° video than for the non-immersive video ($M_{Immersive\ 360°\ video}$ = 3.82 vs. $M_{Non-immersive\ 360°\ video}$ = 3.11; F(1, 317) = 59.219, p < 0.001, Eta^2 = 0.157). Similarly, the effect of time was significant, with a higher level of environmental mental imagery after exposure to 360° video than before ($M_{After\ exposure}$ = 3.71 vs. $M_{Before\ exposure}$ = 3.21; F(1, 317) = 44.164, p < 0.001, Eta^2 = 0.122). In addition, the interaction between video type and time also had a significant effect on environmental mental imagery (F(1, 317) = 34.859, p < 0.001, Eta^2 = 0.099). A t-test was performed for each group to examine this interaction. The results (**Table 3**) revealed a significant difference in participants' environmental mental imagery before and after exposure to 360° immersive video: participants reported higher levels after exposure than before ($M_{After\ exposure\ to\ immersive\ 360°\ video}$ = 4.41 vs. $M_{Before\ exposure\ to\ immersive\ 360°\ video}$ = 3.34; t = -9.139, p < 0.001). On the other hand, no significant difference was observed before and after exposure to non-immersive video ($M_{After\ exposure\ to\ non-immersive\ 360°\ video}$ = 3.28 vs. $M_{Before\ exposure\ to\ non-immersive\ 360°\ video}$ = 3.08; t = -1.644, p > 0.05). Hypothesis H1 is therefore accepted.

Hypotheses H2, H3 and H4 were tested via two moderated mediation analysis using Hayes' macro-process, model 14 (Hayes, 2018), with a 5000-bootstrap method. In order to

Table 3. Results of ANOVA and simple effects t-tests by group

ANOVA						
			Dependent variable			
			Mental imagery			
			M	F	p	Eta^2
360° video	Non immersive (**N=161**)		3.11	59.219	0.000	0.157
	Immersive (**N=158**)		3.82			
Time	Before		3.21	44.164	0.000	0.122
	After		3.71			
360° video * Time	Non immersive	Before	3.08	34.859	0.000	0.099
		After	3.14			
	Immersive	Before	3.34			
		After	4.29			

Simple effects t-tests by group					
		Dependent variable			
		Mental imagery			
		Mean	t	Ddl	P
Non immersive (**N=161**)	Before	3.08	-1.644	320	0.101
	After	3.28			
Immersive (**N=158**)	Before	3.34	-9.139	314	0.000
	Afyer	4.41			

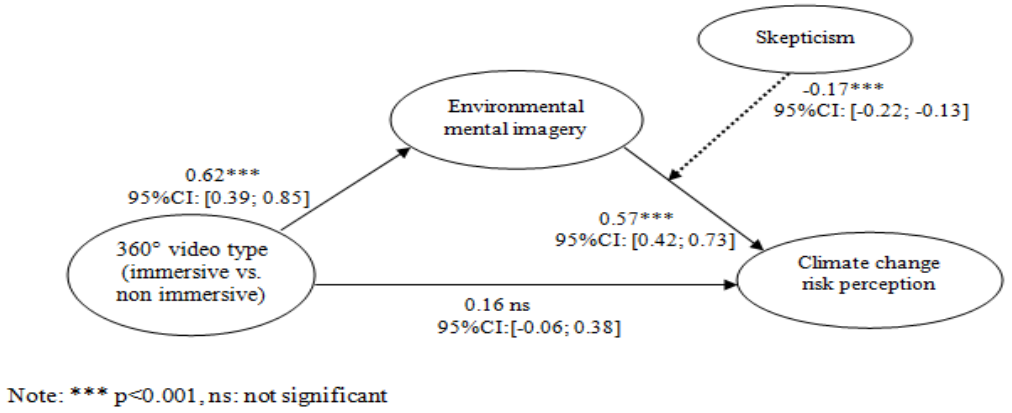

Figure 2. Moderated mediation analysis (Source: Authors' own elaboration)

maintain statistical power, it was decided not to dichotomize the moderating variable, namely skepticism (Fitzsimons, 2008).

The results obtained from the first analysis (**Figure 2**) revealed that video type (immersive or not) has a significant and positive impact on environmental mental imagery (β = 0.62; p < 0.001). Environmental mental imagery, in turn, positively influenced climate change risk perception (β = 0.57; p < 0.001), supporting H2. Nevertheless, the direct effect of video type on climate change risk perception was not significant (β = 0.16; p > 0.05). These results indicate a total mediation of environmental mental imagery in the relationship between video type and climate change risk perception. Furthermore, the results show the presence of a significant and negative interaction effect between environmental mental imagery and skepticism on climate change risk perception (M*W = -0.17; 95%CI: -0.22 to - 0.13), supporting H4a. In other words, a higher level of skepticism attenuates the impact of environmental mental imagery on climate change risk perception. This suggests that, despite the strong potential of mental imagery, high skepticism may reduce awareness of the risks associated with climate change.

The results obtained from the second analysis (**Figure 3**) revealed that video type (immersive or not) has a significant and positive impact on environmental mental imagery (β = 0.62; p < 0.001). Environmental mental imagery, in turn, positively influenced attitude towards climate change mitigation behaviors (β = 0.34; p < 0.001), supporting H3. Nevertheless, the direct effect of video type on attitude towards climate change mitigation was not significant (β = 0.05; p > 0.05). These results indicate a total mediation of environmental mental imagery in the relationship between video type and attitude towards climate change mitigation behaviors. Furthermore, the results show the presence of a significant and negative interaction effect between environmental mental imagery and skepticism on attitude towards climate change mitigation behaviors (M*W = -0.06; 95%CI: -0.07 to -0.04), supporting H4b. In other words, higher levels of skepticism mean that environmental mental imagery has less positive influence on attitudes towards actions to mitigate climate change. So, while environmental mental imagery may encourage a favorable attitude towards these behaviors, a high level of skepticism tends to limit this effect.

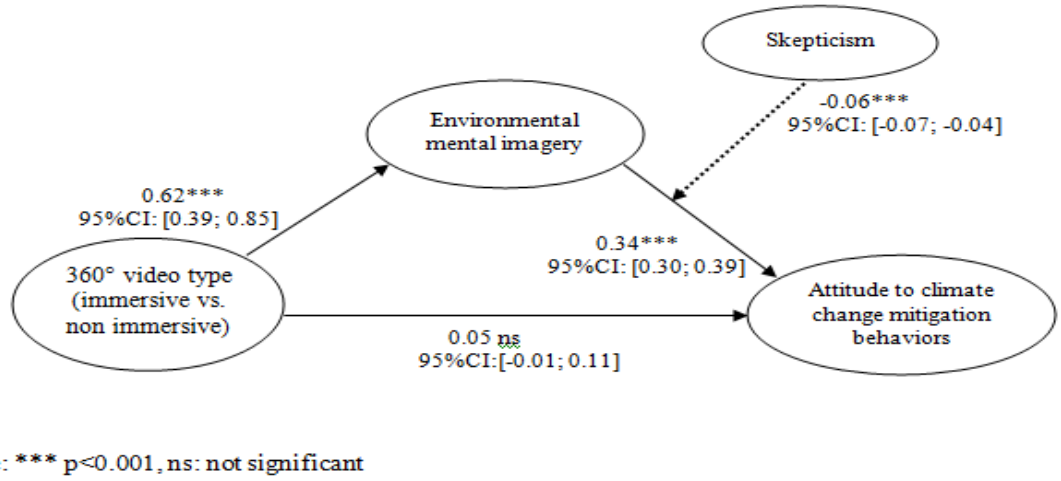

Figure 3. Moderated mediation analysis (Source: Authors' own elaboration)

DISCUSSION

This experimental study examined the effect of immersive 360° video (vs. non-immersive) on environmental mental imagery in two phases "before" and "after" exposure. The results show that exposure to 360° immersive video increases participants' environmental mental imagery more than non-immersive exposure. This outcome aligns with previous studies (Bogicevic et al., 2019; Fan et al., 2022; Skard et al., 2021; Zhang et al., 2024) conducted in different contexts, which have shown that exposure to immersive VR video increases mental imagery.

The results also demonstrate a positive effect of environmental mental imagery on individuals' perception of climate change risks and their attitudes supporting mitigation behaviors. These findings corroborate the works of Leiserowitz (2006) and Smith and Leiserowitz (2012), which revealed that mental imagery is a major predictor of climate risk perception. Moreover, they corroborate earlier studies conducted by Holmes et al. (2008), Karlsson et al. (2024), Renner et al. (2019), according to which mental imagery is capable of triggering emotional and affective responses, thereby reinforcing pro-environmental attitudes (Chen & Wu, 2023).

Furthermore, moderation analyses show that skepticism negatively moderates the effect of environmental mental imagery on climate change risk perception and attitude towards climate change mitigation behaviors. These results are consistent with the observations of Akter et al. (2012) and Engels et al. (2013), who demonstrate that climate skepticism has a negative impact on mitigation and adaptation measures. Thus, although environmental mental imagery promotes climate change risk perception and attitude towards climate change mitigation behaviors, the effect of this influence diminishes in more skeptical individuals, underscoring the importance of reducing skepticism to optimize the effectiveness of immersive interventions to promote climate change awareness. However, some work reports limited effects of VR in environmental education. For example, Makransky et al. (2019) showed that immersion via VR headset increases subjective presence but decreases learning performance, due to cognitive overload. Furthermore, Markowitz et al. (2018) found that although immersive VR promotes knowledge gains and interest in climate change, its effects can quickly fade without a reinforced pedagogical anchor. In addition, cultural influences can modulate the response to VR. Social norms, previous exposure to technology and institutional trust, variables that are highly dependent on the local context, can alter the impact of immersion (Doyle, 2009; Lorenzoni & Hulme, 2009). For example, a Tunisian population directly confronted with heatwaves and drought may experience greater resonance than an audience from less exposed regions, suggesting the importance of adapting VR devices to local culture, lived experiences and local narratives.

CONCLUSION

The results of this study make significant theoretical contributions to the literature on climate change. Firstly, the study positions environmental mental imagery as a crucial predictor of climate change risk perception and attitudes towards mitigation behaviors. By showing that mental imagery, generated by immersive 360° experiences can induce favorable affective and cognitive responses; this research proposes an alternative to traditional cognitive models and highlights the potential of imagery to bring about changes in perception and attitude towards environmental risks.

Secondly, the study introduces climate skepticism as a moderator of the effects of mental imagery, thereby enriching our understanding of this complex variable. The results show that climate skepticism limits the positive influence of environmental mental imagery on risk perception and attitudes towards mitigation behaviors, highlighting the challenge that this skepticism represents in climate awareness campaigns. Consequently, this study proposes that awareness-raising interventions based on mental imagery should be adapted to overcome the psychological barriers posed by climate skepticism. These theoretical contributions thus encourage researchers to develop differentiated strategies that maximize the effectiveness of immersive approaches, taking into account the moderating effect of skepticism.

The results of this study also reveal important managerial implications for climate awareness campaigns. Firstly,

communication managers and NGOs (Non-Governmental Organizations) can take advantage of immersive VR to reinforce the impact of their climate messages. The use of immersive 360° videos via VR headsets is proving to be a strategic tool for creating memorable experiences that reinforce environmental mental imagery, thereby fostering a heightened perception of climate change risks and encouraging the adoption of mitigation behaviors. These results suggest that it is more effective to invest in immersive 360° videos than in less immersive formats to capture attention and stimulate environmental engagement. Consequently, project managers can allocate their communications budgets to more immersive VR media rather than non-immersive formats, optimizing resources for greater impact.

The moderating role of climate skepticism also highlights the importance of segmenting campaigns according to audience levels of skepticism and adapting messages accordingly. For skeptical audiences, incorporating information, scientific data and testimonials into immersive videos can reinforce the effect of mental imagery and help reduce cognitive barriers. By effectively targeting these segments and using immersive technologies strategically, campaigns can maximize their reach and impact, raise awareness of climate risks and encourage mitigation behaviors.

Furthermore, companies and governments wishing to promote sustainable behaviors can also use VR experiences to raise awareness among their stakeholders. For example, at conferences or public events, VR stands could provide the public with immersive experiences, increasing their awareness of climate issues. In urban settings such as shopping malls, events or even public spaces, offering immersive VR experiences that are accessible to citizens, particularly in high-traffic areas, could encourage a wider audience to consider mitigation behaviors after being exposed to a memorable immersive experience.

This study has certain limitations that should be considered for future research. Firstly, the sample consisted of participants recruited in a shopping centre in Tunisia, which may restrict the generalization of the results to other geographical or cultural contexts. Several studies (Datta & Datta, 2024; Shtessel, 2023) have shown that the perception of climate risks varies from one country to another. It would therefore be relevant to conduct additional cross-cultural studies to corroborate the results of this research. Furthermore, this research focuses on an experience at a given point in time, without assessing the long-term effects of exposure to immersive videos on mental imagery, perception of climate risk or attitudes towards mitigation behaviors. It would therefore be crucial to carry out longitudinal studies to assess the durability of the effects of 360° immersive exposure. Another avenue of research can be considered to examine the impact of different types of narrative and content in immersive videos to identify the elements that mostly reinforce environmental mental imagery. Finally, research could also incorporate other moderating variables, such as preexisting knowledge about climate change (Barnidge et al., 2022) and self-efficacy (Van Valkengoed et al., 2024).

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