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Abstract

Purpose As virtual reality (VR) technology continues to advance, its potential impacts and applications on the tourism industry become increasingly significant. This study aims to deepen the understanding of VR's role in influencing tourists' attitudes and sustainable VR tourism intention. This study also seeks to compare the effectiveness of VR CAVE versus desktop VR.

Design/methodology/approach Data was gathered through two methods. One group of participants was invited to a laboratory equipped with VR CAVE and another group of respondents was recruited from an online panel to test the effectiveness of using desktop VR. Data was analyzed using SmartPLS 4.0 for path significance and group differences.

Findings The findings revealed that the perceived values of the VR experience significantly influenced VR immersion including presence and flow. VR immersion subsequently influenced attitudes towards destinations, attitudes towards VR tourism and sustainable VR tourism intentions. The results of multigroup analysis indicated minor differences between both VR system setups.

Originality These findings advance the understanding of VR's influence on tourists' attitudes and sustainable VR tourism intentions. Notably, the study highlights the efficacy of cost-effective VR setups in effectively shaping tourists' attitudes and motivating sustainable VR tourism intentions.

Keywords: virtual tourism; VR systems; sustainable travel; sustainability; immersion; flow experience

1. Introduction

Amidst advancements in telecommunication devices and internet accessibility, virtual reality (VR) has emerged as a powerful tool with significant implications for the tourism industry and it allows users to engage in immersive experiences that stimulate real-world travel (Soliman et al., 2021). The utilization of VR in the tourism industry allows businesses to offer virtual tours to destination, accommodations and attractions for marketing purposes, support the training of industry professionals in realistic scenarios, and enables tourism businesses to provide virtual experience for pre-trip planning, exploration of destinations and ultimately as sustainable travel alternatives (Beck et al., 2019; Guttentag, 2010; Oncioiu & Priescu, 2022). As VR enables individuals to experience destinations without physically travelling there, it presents a unique opportunity to reduce the negative environmental impacts of travel, while still satisfying the demand for exploration and discovery (Leung et al., 2022; Wei, 2019).

Despite the potential of VR in promoting sustainable tourism, the majority of prior studies focused on the marketing application of VR in the tourism industry, for example, hotel booking (Lo & Cheng, 2020) and visit intentions (Kim et al., 2020). Although some studies examined how VR can influence sustainable tourism practices and behaviors (Leung et al., 2023; Talwar et al., 2022), these studies are often relied on the past VR activities carried out by the respondents. Furthermore, the recent studies on VR tourism focused on the use of head-mounted displays (a wearable device), but less often on VR CAVE (a real space with

multiple screens surrounding the user) and desktop VR (a 3D virtual environment displayed on a computer monitor) (Beck et al., 2019). This leaves a significant gap in understanding how different types of VR technologies, particularly VR CAVE and desktop VR, influence user behavior and sustainable VR tourism intentions.

VR CAVE offers an immersive and engaging experience through its projection system (Buttussi & Chittaro, 2017) and its market was valued at $14.8 billion in 2023 and projected to reach $26.71 billion by 2031 (Nuance Market Research, 2024). Despite its potential, VR CAVE has received less research attention than head-mounted displays (HMD) which dominate VR studies (e.g. Huang & Roscoe, 2021; Wu et al., 2020). The HMD market was projected to grow from $7.5 billion in 2024 to $26.4 billion by 2029 (Markets and Markets, 2024). Meanwhile, desktop VR, a more accessible option for 3D virtual tours, was valued at $0.96 billion in 2023 and is expected to grow at an annual rate of 27.9%, reaching $17.88 billion by 2035 (Allied Market Research, 2024). Prior studies have produced inconsistent results, with more resource-intensive VR systems not always yielding superior outcomes (e.g. Huang & Roscoe, 2021; Lee & Wong, 2014). Given the growing potential and popularity of both VR CAVE and desktop VR, there is a need to compare their impacts directly. This study aims to fill this gap by examining how VR CAVE and Desktop VR influence sustainable VR tourism intentions. By comparing these two setups, this study would provide valuable insights into their relative effectiveness and offer guidance for tourism businesses on investing in advanced or cost-effective VR technologies. The objectives of this study are as follows:

- To examine how VR experience influences tourists' attitudes towards VR tourism and sustainable VR tourism intentions.
- To compare the effectiveness of VR CAVE and desktop VR for delivering VR experiences.
- To discuss the implications of using VR in influencing tourists' attitude and intentions and the considerations for investing in VR system setups.

2. Literature Review

2.1 Theory of Consumption Values

The Theory of Consumption Values (TCV) explains how consumers make decisions based on the multi-dimensional perceived values (Sheth et al., 1991). Sánchez et al. (2006) devised a scale specifically designed to assess three fundamental types of perceived value in tourism products: functional, hedonic, and social. Although their work primarily addresses the environmental setup, product features and services of tourism products, the concept of perceived values has been widely applied to understand the customer perceived experience in the context of tourism and hospitality research as well as related technology studies, e.g. impulse purchases on tourism websites (Chen et al., 2019), VR experiences of amusement rides (Jung et al., 2018), and smart home technology in peer-to-peer accommodation (Papagiannidis & Davlembayeva, 2022).

2.1.1 Utilitarian Value

Utilitarian value generally refers to practical benefits of consumption (Ling et al., 2021; Nikhashemi et al., 2021). In the context of VR tourism, utilitarian value is realized through the technology's capabilities by bringing the user to various locations and environments, including those that are challenging or impossible to visit in real life (Talwar et al., 2022). This value is reflected in users' perceived usefulness, helpfulness, and importance of the VR experience (Shamim et al., 2024). Through provision of relevant and useful experience, customers can more effectively engage with and benefit from the VR experience that leads to a higher level of immersion (Jamshidi et al., 2018).

2.1.2 Hedonic Value

Lv and Wu (2021) defined hedonic value as an efficient and pleasant sensory experience of visual or emotional pleasure. VR technology provides individuals with enjoyable experience in thrilling adventures, exploring new places and engaging in activities that might not be feasible in real-world tourist spots (Damjanov & Crouch, 2019). The hedonic value associated with VR is crucial for enhancing the immersive quality of virtual tourism experiences, driven by the interactive elements, personalization, and emotional engagement it offers (Buhalis et al., 2019). By delivering pleasant and enjoyable experiences, VR technology not only provides users with a profound sense of enjoyment but also enriches the immersive experience for the users (Fan et al., 2022).

2.1.3 Social Value

Social value refers to the alignment of a consumer's image with the social standards of their peers and the social image they aim to project (Caniëls et al., 2021). It encompasses people's concern for their own reputation and the impact they have on the groups they belong to (Han, 2021). Unlike conventional travel, VR tourism offers an alternative by providing not only an immersive experience but also a sustainable form of tourism. Through VR tourism experiences, customers can derive social value by building relationships and creating a favorable impression on others, which in turn enhances the overall immersive experience in VR tours (Shin & Kang, 2024). Similarly, Natarajan et al. (2024) suggested that social value, as an integral part of the virtual experience, contributes to greater perceived immersion and engagement.

2.2 VR Immersion

Slater (2018) defined VR immersion as an objective quality of a VR system where high immersiveness indicates the system's ability to deliver rich sensory and motor experiences and respond to users' actions dynamically. In contrast, Witmer and Singer (1998) defined immersion as a psychological state in which users feel embedded within and actively engaged with an environment that continuously provides stimuli and experiences. Szabó and Gilányi (2020) distinguish these as "technological immersion" that focuses on the system's immersing qualities, and "psychological immersion" that emphasizes the user's subjective experience.

This study focuses on psychological immersion because it directly reflects users' subjective experiences which are central to understanding how VR can influence attitudes and behaviors in tourism contexts. As psychological immersion is concerned with the user's internal experience, we conceptualized VR immersion into two constructs, i.e. presence and flow

experience (Kim & Ko, 2019). In the context of tourism research, presence refers to subjective feeling of physically present in the simulated setting (e.g. destinations, attractions or accommodation, etc.) and this feeling influences users' engagement and involvement in the VR experience (Gibbs et al., 2022). On the other hand, the flow experience refers to the feeling of delight and absorption during a VR activity. A high level of flow state is often associated with the users' level of concentration, loss of time perception, and sense of enjoyment (Michailidis et al., 2018). The presence and flow are closely related to an overall VR immersion that results in a more favorable assessment of the application and increased willingness to use it in the future (Kim & Ko, 2019).

Prior studies have demonstrated the significant impact of perceived values on VR experience. For instance, Yu et al. (2024) demonstrated that a positive VR tourism experience enhances the user enjoyment, while Sihi (2018) found that the realism and quality of a VR experience increases the involvement of the customers. Similarly, Hudson et al. (2019) suggested that a well-designed VR environment encourages users to actively interact and that leads to a more optimal experience. Building on these findings, we argue that when users perceive a VR experience as useful, entertaining and meaningful, they become more engaged (Bender & Sung, 2021), which, in turn, enhances their psychological immersion.

Thus, the following hypotheses are proposed.

Hypothesis 1 (H1): Utilitarian value is positively related to (a) presence and (b) flow.
Hypothesis 2 (H2): Hedonic value is positively related to (a) presence and (b) flow.
Hypothesis 3 (H3): Social value is positively related to (a) presence and (b) flow.

2.3 Influence of VR Immersion on Attitudes and Sustainable VR Tourism Intentions

2.3.1 Attitude towards Destination

In the context of tourism, attitude refers to tourists' dispositions towards destinations and the related tourism products and services (Xu et al., 2023). VR offers a compelling way to engage potential customers by providing accessible and vivid virtual previews of destinations (Geng et al., 2023). Prior studies have showed that when users experience psychological flow and presence in an engaging and realistic VR experience, attitudes towards travel destinations is enhanced (Nam et al., 2023; Tussyadiah et al., 2017). As users experience destinations in a immersive VR environment, their attitudes and predispositions towards these destinations can be positively influenced (Alyahya & McLean, 2022). Therefore, the following hypothesis is proposed.

Hypothesis 4 (H4a): Presence is positively related to attitude towards destination.
Hypothesis 4 (H4b): Flow is positively related to attitude towards destination.

2.3.2 Attitude towards VR tourism

Users' attitude towards VR tourism can be considered as users' subjective appraisal of the VR system and it is affected by the immersive experience provided by the VR (Chung et al., 2018). Tussyadiah et al. (2018) argued that the perceived enjoyment of the VR experience significantly influences attitudes towards VR tourism. Previous research suggested that a higher level of VR presence and flow improved users' engagement in the virtual environment and heightened pleasure during a VR encounter (Lee & Jan, 2022). Past studies focusing on

the role of technology adoption provided empirical evidence of how VR benefits, features, and user experiences influence attitudes towards VR tourism (e.g. Huang, 2023). Therefore, the following hypothesis is proposed.

Hypothesis 5 (H5a): Presence is positively related to attitude towards VR tourism.
Hypothesis 5 (H5b): Flow is positively related to attitude towards VR tourism.

2.3.3 Sustainable VR Tourism Intention

Tourists increasingly prioritize environmentally and socially responsible travel (Yersüren & Özel, 2024). In this study, sustainable VR tourism intention refers to customers' intent to utilize VR technology for environmentally friendly and sustainable travel purposes (Hoang et al., 2023). Researchers revealed that VR experiences have a positive influence on sustainable travel intentions (Lin et al., 2020) by enhancing presence and flow, which in turn foster greater environmental empathy and emotional connection with destinations, ultimately strengthening travellers' intentions to engage in sustainable tourism (Hofman et al., 2022). VR experiences can help raise travelers' knowledge of sustainability issues and encourage them to travel more sustainably (Seyfi et al., 2022). Particularly, experiences with high levels of immersion are likely to foster stronger intentions to engage in sustainable travel (Chang & Chiang, 2022). Thus, the following hypothesis is proposed.

Hypothesis 6 (H6a): Presence is positively related to sustainable VR tourism intention.
Hypothesis 6 (H6b): Flow is positively related to sustainable VR tourism intention.

2.4 VR CAVE vs. Desktop VR

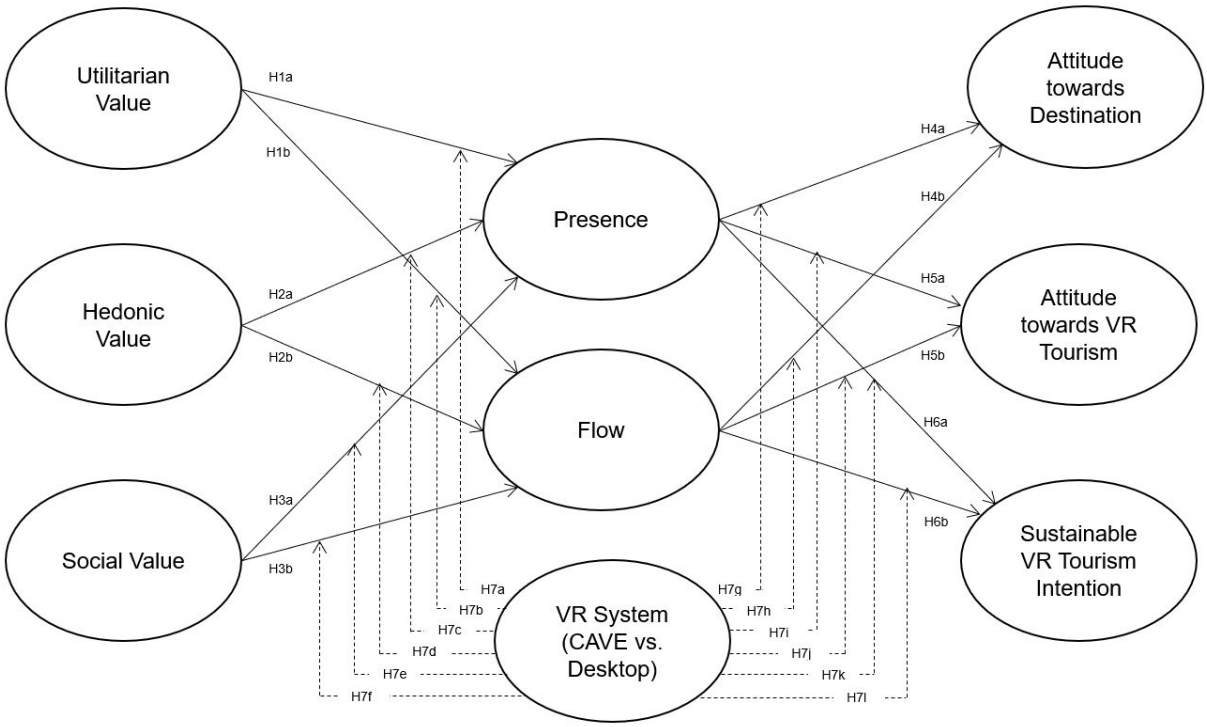
VR CAVE and desktop VR are two prevalent setups, and each offers distinct benefits and drawbacks (Shadiev & Li, 2022). VR CAVE are physical spaces with multiple screens surrounding the user, providing a fully immersive setting (Westmattelmann et al., 2021). However, constructing and maintaining VR CAVE require significant resources, and only a limited number of users can access them simultaneously (Bower et al., 2020). Desktop VR refers to a virtual environment displayed on a computer monitor, enabling interactive exploration through various computer input devices such as a keyboard, mouse, or touch screen, along with headphones for audio outputs (Makransky & Petersen, 2019). This offers a more affordable way for users to experience VR (Lee & Wong, 2014). However, desktop VR lacks the sense of physical immersion provided by VR CAVE (Pellas et al., 2021).

Previous studies showed inconsistent findings regarding the effectiveness of these different VR systems. Some suggested no significant difference in the user experience between VR system setups (Huang & Roscoe, 2021; Krijn et al., 2004). This potentially indicated that VR exposure can be effective with lower-cost and easily accessible setups (Emmelkamp et al., 2002). However, a few studies have shown otherwise, for example Wu et al. (2020) conducted a meta-analysis that VR immersion is superior in head-mounted displays, yet with small effect sizes. Leung et al. (2023) found that while desktop VR excels in delivering aesthetic and educational experiences, VR headsets are more effective for entertainment and escapist experiences. Given these inconsistent findings, we hypothesize that the type of VR system may moderate the relationship between perceived values and psychological immersion (i.e., presence and flow), as well as the connection between psychological immersion, attitudes, and sustainable VR tourism intentions. We argue that the immersive nature of VR systems (i.e. VR CAVE) may

strengthen these relationships by providing a more realistic and engaging experience comparing to less sophisticated setup (i.e. desktop VR).

Hypothesis 7 (H7): The relationships in the research model differ between VR CAVE and desktop VR.

The research model of this study is presented in Figure 1.



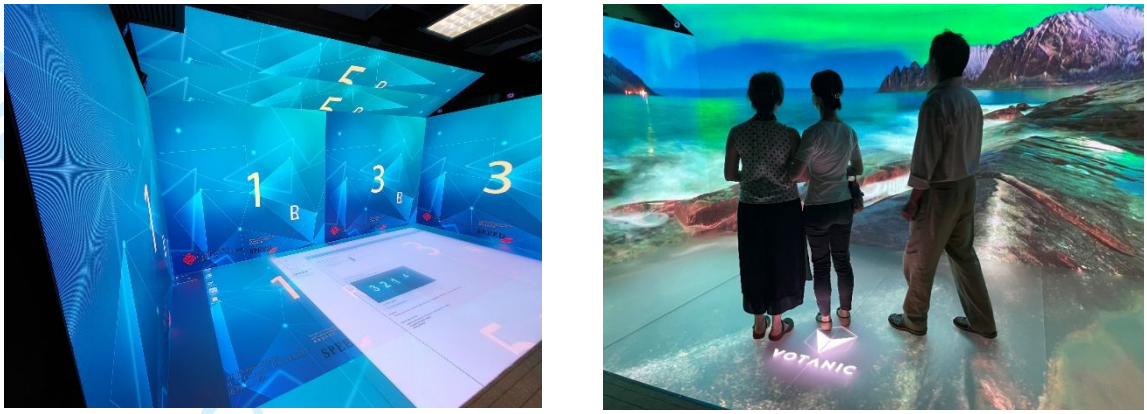
Source: Authors' own work

Figure 1 The research model

3. Methods

3.1 Research Design and Data Collection

To evaluate effectiveness of VR CAVE versus desktop VR, data was gathered through two methods. First, participants were invited to a laboratory installed with VR CAVE located within the researcher's institution (Figure 2). Second, an online panel of a Chinese marketing research agency was utilized to test the effectiveness of desktop VR.



Source: Authors' own work

Figure 2 VR CAVE utilized in this study

Both employed the identical procedures. Ethical approval was obtained from the research committee of the author's institution. The respondents were first presented with the information about the research study, including its objectives, potential risks associated with VR immersive experiences (such as dizzinessand eye strain), and the confidentiality and anonymity of the collected data. Upon providing their consent, respondents were directed to watch two 360-degree videos showcasing tourism experiences in Norway (https://youtu.be/fNsYzXDJg_8) and Jordan (https://youtu.be/xSiv4TkfSOE) respectively. The videos showcase scenic views of the two destinations with minimal voice-over, ensuring that the VR experience remains unaffected by other confounding variables. To validate their effectiveness, a pretest was also conducted with 15 participants who assessed the videos' immersive qualities. In the VR CAVE setting, the research team provided assistance to the respondents in viewing the two videos. On the other hand, the online platform utilized a web analytics mechanism to verify that respondents viewed both videos on the appropriate browsers and desktop devices. This ensured they had the intended desktop VR experience. Respondents were then directed to complete the questionnaire. In the VR CAVE setting, respondents were given a voucher of HKD 50 (~USD 6.5) as a token of appreciation for their participation. Similarly, the online platform implemented its own incentivization approach to reward the respondents for their participation. The data was collected from March to June 2023.

3.2 Questionnaire Design

These measurement items were adapted from validated scales used in previous studies (Appendix A). The questionnaire gathered responses to measurement items related to the constructs within the research model in a 7-point scale. Respondents were also asked to provide their demographic information, including gender, age, and educational level.

3.3 Data Analysis

We adopted partial least squares structural equation modeling (PLS-SEM) with SmartPLS 4 due to its distinct advantages, i.e. its suitability for studies with a large number of constructs and complex path relationships and its ability to operate without strict assumptions about normal data distribution (Hair Jr et al., 2017). Furthermore, to compare the effectiveness of using VR CAVE and desktop VR in influencing tourists' attitudes and sustainable VR tourism intention, a multigroup analysis (MGA) would be conducted by following the procedures outlined by Henseler et al. (2016).

4. Findings

4.1 Respondents' Profile

A total of 253 usable responses were received (126 for VR CAVE and 127 for desktop VR). Among these, 6 participants in the VR CAVE group declined to participate in the survey and 8 participants in the desktop VR group returned incomplete questionnaires. The respondents' profiles for each group and the combined profile are presented in Table 1.

Table 1 Respondent Profile

Attributes	Category	VR CAVE		Desktop VR		Combined	
		N	%	N	%	N	%
Gender	Male	41	32.5	69	54.3	110	43.5
	Female	85	67.5	58	45.7	143	56.5
Age	≤ 24	45	35.7	12	9.4	57	22.5
	25-34	23	18.3	78	61.4	101	39.9
	35-44	31	24.6	32	25.2	63	24.9
	45-54	23	18.3	4	3.1	27	10.7
	≥ 55	4	3.2	1	0.8	5	2.0
Education Level	Secondary or below	21	16.7	5	3.9	26	10.3
	Sub-degree (including associate degrees and diplomas)	15	11.9	11	8.7	26	10.3
	Bachelor's degree	29	23.0	101	79.5	130	54.4
	Master's degree or above	61	48.4	10	7.9	61	28.0
Previous VR Tourism Experience	Yes	68	54.0	40	31.5	108	42.7
	No	58	46.0	87	68.5	145	57.3

Source: Authors' own work

4.2 Measurement Model

Following the assessment guidelines stipulated by Hair et al. (2019), the loadings of all latent variables' measurement items exceeded the 0.708 threshold and all the indicators of the constructs in the research model were significant. The results also showed that the Cronbach's alpha and composite reliability of all constructs were above 0.70, and this confirmed the internal consistency and reliability of the constructs. Moreover, the Average Variance Extracted (AVE) of all constructs was greater than the 0.5 threshold, and this confirmed the convergent validity of the measurement model (Table 2). The Variance Inflation Factor (VIF) value for all constructs' indicator were less than the 5.0 threshold (Hair et al., 2017) indicating that multicollinearity was not a concern.

Table 2 Reliability and Validity

Constructs	Items	Factor Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Utilitarian Value (UV)	UV1	0.774	0.837	0.902	0.755
	UV2	0.911			
	UV3	0.915			
Hedonic Value (HV)	HV1	0.883	0.876	0.923	0.801
	HV2	0.897			
	HV3	0.905			
Social Value (SV)	SV1	0.930	0.914	0.946	0.854
	SV2	0.916			
	SV3	0.926			
Presence (PRE)	PRE1	0.887	0.816	0.889	0.729
	PRE2	0.855			
	PRE3	0.832			
Flow (FLO)	FLO1	0.901	0.910	0.935	0.783
	FLO2	0.912			
	FLO3	0.875			
	FLO4	0.851			
Attitude towards Destination (ATT_D)	ATT_D1	0.887	0.875	0.923	0.800
	ATT_D2	0.916			
	ATT_D3	0.880			
Attitude towards VR Tourism (ATT_VR)	ATT_VR1	0.896	0.860	0.914	0.780
	ATT_VR2	0.868			
	ATT_VR3	0.885			
Sustainable VR Tourism Intention (SVI)	SVI1	0.880	0.819	0.892	0.734
	SVI2	0.845			
	SVI3	0.845			

Source: Authors' own work

Furthermore, discriminant validity was assessed using the Heterotrait and Monotrait (HTMT) ratio (Henseler et al., 2015) (Table 3). The values for all constructs were less than the recommended threshold 0.90.

Table 3 HTMT ratios

	UV	HV	SV	PRE	FLO	ATT_D	ATT_VR
Utilitarian Value (UV)							
Hedonic Value (HV)	0.897						
Social Value (SV)	0.825	0.692					
Presence (PRE)	0.884	0.872	0.830				
Flow (FLO)	0.847	0.883	0.812	0.889			
Attitude towards Destination (ATT_D)	0.800	0.714	0.630	0.756	0.845		
Attitude towards VR Tourism (ATT_VR)	0.805	0.742	0.804	0.842	0.779	0.717	
Sustainable VR Tourism Intention (SVI)	0.899	0.843	0.789	0.876	0.726	0.708	0.863

Source: Authors' own work

4.3 Path Analysis

The model explained 76.6% and 69.9% of the variance in VR presence and flow, respectively, as well as 42.3% in attitude towards destination, 57.8% in attitude towards VR tourism, and

41.7% in sustainable VR tourism intention. The $PLS_{predict}$ analysis showed that all Q^2 values were larger than zero, therefore predictive relevance was established. Only a minority of the indicators (2 out of 14) showed a higher prediction error in terms of RMSE compared to the LM analysis of the PLS-SEM analysis, indicating a moderate level of predictive power for the structural model (Shmueli et al., 2019).

The path analysis revealed that utilitarian value ($\beta = 0.163$, $p < 0.05$), hedonic value ($\beta = 0.460$, $p < 0.001$) and social value ($\beta = 0.335$, $p < 0.01$) positively influenced VR presence, therefore H1a, H2a and H3a were supported. In addition, utilitarian value ($\beta = 0.225$, $p < 0.01$), hedonic value ($\beta = 0.431$, $p < 0.001$) and social value ($\beta = 0.257$, $p < 0.001$) positively influenced flow, therefore H1b, H2b and H3b were supported.

Presence positively influenced attitude towards destination ($\beta = 0.484$, $p < 0.001$), attitude towards VR tourism ($\beta = 0.544$, $p < 0.001$) and sustainable VR tourism intention ($\beta = 0.522$, $p < 0.001$). Similarly, flow positively influenced attitude towards destination ($\beta = 0.210$, $p < 0.05$), attitude towards VR tourism ($\beta = 0.237$, $p < 0.01$) and sustainable VR tourism intention ($\beta = 0.428$, $p < 0.001$). Thus, H4a, H4b, H5a, H5b, H6a and H6b were supported (Table 4).

Table 4 PLS-SEM path analysis

Path		β	*t*	*p*	Supported
H1a	Utilitarian Value → VR Presence	0.163	2.302	0.021	Yes
H1b	Utilitarian Value → Flow	0.225	2.841	0.005	Yes
H2a	Hedonic Value → VR Presence	0.460	6.283	0.000	Yes
H2b	Hedonic Value → Flow	0.431	5.470	0.000	Yes
H3a	Social Value → VR Presence	0.335	6.423	0.000	Yes
H3b	Social Value → Flow	0.257	4.232	0.000	Yes
H4a	Presence → Attitude towards Destination	0.484	4.510	0.000	Yes
H4b	Flow → Attitude towards Destination	0.210	1.983	0.047	Yes
H5a	Presence → Attitude towards VR Tourism	0.544	5.570	0.000	Yes
H5b	Flow → Attitude towards VR Tourism	0.237	2.433	0.015	Yes
H6a	Presence → Sustainable VR Tourism Intention	0.522	5.020	0.000	Yes
H6b	Flow → Sustainable VR Tourism Intention	0.428	5.344	0.000	Yes

Source: Authors' own work

4.4 Multigroup Analysis

The Measurement Invariance of Composite Models (MICOM) procedure outlined by Henseler et al. (2016) was used to assess whether the data from two groups are statistically meaningful for MGA. First, as the measurement items and algorithm setting for both groups were identical, therefore the requirement of configural invariance was met. Second, the correlation *c* and the 5% quantile were compared that the correlation values exceeded the 5% quantile for all constructs. This was further supported by permutation *p*-values greater than 0.05, compositional invariance across the constructs was established. Third, the equality of means and variances across the two groups were, however, not met as certain constructs' original mean value and variance difference did not fall between the upper and lower bounds of the 95% confidence interval. Thus, partial measurement invariance was established which permits MGA by comparing path coefficients across the two groups.

The results of MGA are presented in Table 5. Out of the twelve paths, seven were consistent across both. However, three paths showed significantly stronger relationships in the VR CAVE group compared to desktop VR: the link between utilitarian value and flow (H7b), presence and attitude towards VR tourism (H7i), and flow and sustainable VR tourism intention (H7l).

Specifically, the findings revealed that utilitarian value had a significant positive effect on flow in the VR CAVE group ($\beta = 0.513$, $p < 0.001$), while this relationship was not significant for the desktop VR group. Furthermore, VR presence had a stronger impact on both attitudes towards VR tourism (H7i) for respondents in the VR CAVE group compared to those in the desktop VR group; whereas flow had a stronger impact on sustainable VR tourism intention (H8l). Interestingly, the findings showed that social value significantly influenced VR presence using desktop VR ($\beta = 0.478$, $p < 0.001$) while this path was not significant among those in the VR CAVE group (H7e). Moreover, the desktop VR group exhibited a stronger link between presence and sustainable VR tourism intention (H7k) than the VR CAVE group. Overall, the analysis revealed two notable differences: social value significantly influenced VR presence in the desktop VR group but not in the VR CAVE group, while utilitarian value significantly impacted flow in the VR CAVE group but was non-significant in the desktop VR group.

Table 5 MGA for VR CAVE vs. Desktop VR

Path		*Path Coefficients*		*p*-value		*Coefficient Difference*		
		VR CAVE	**Desktop VR**	**VR CAVE**	**Desktop VR**	**Difference**	***p*-value**	***Significant Different?***
H7a	Utilitarian Value → Presence	0.331	0.184	0.044	0.076	0.146	0.377	No
H7b	Utilitarian Value → Flow	0.513	0.176	0.000	0.088	0.336	0.032	Yes
H7c	Hedonic Value → Presence	0.385	0.328	0.052	0.046	0.057	0.698	No
H7d	Hedonic Value → Flow	0.213	0.302	0.699	0.602	-0.089	0.584	No
H7e	Social Value → Presence	0.173	0.478	0.082	0.000	-0.305	0.018	Yes
H7f	Social Value → Flow	0.208	0.375	0.062	0.000	-0.167	0.197	No
H7g	Presence → Attitude towards Destination	0.714	0.466	0.000	0.000	0.247	0.257	No
H7h	Flow → Attitude towards Destination	0.001	0.127	0.718	0.564	-0.126	0.590	No
H7i	Presence → Attitude towards VR Tourism	0.841	0.653	0.000	0.000	0.188	0.005	Yes
H7j	Flow → Attitude towards VR Tourism	0.009	0.272	0.889	0.233	-0.263	0.168	No
H7k	Presence → Sustainable VR Tourism Intention	0.237	0.686	0.082	0.000	-0.448	0.029	Yes
H7l	Flow → Sustainable VR Tourism Intention	0.403	0.020	0.023	0.032	0.383	0.036	Yes

Source: Authors' own work

5. Discussion and Conclusions

5.1 Conclusions

This study examined how VR experiences influence tourists' attitudes and sustainable VR tourism intentions and compared the effectiveness of VR CAVE and desktop VR setups. The results showed that perceived values significantly affected VR immersion, which in turn shaped attitudes toward destinations, attitudes toward VR tourism, and sustainable VR tourism intentions. Furthermore, the MGA analysis indicated only minimal differences between VR CAVE and desktop VR setups.

5.2 Theoretical Implications

The findings of this study contribute to the literature by examining the relationships between perceived values, VR immersion, tourists' attitudes towards destination, attitudes towards VR tourism and sustainable VR tourism intention. The findings deepen the understanding of how functional, hedonic, and social values shape the VR tourism experience and subsequently impact presence and flow. Consistent with previous studies (Buhalis et al., 2019; Yang & Han, 2021), the results confirmed that all three perceived values significantly influence presence and flow. This also demonstrated the applicability of TVC in understanding VR experiences. Our findings are also consistent with Kim and Ko (2019) who found favorable VR experiences significantly influences attitudes towards destinations and VR tourism. Furthermore, our study revealed that VR experiences provide not only realistic imagery of destinations but also subtly remind users of the environmental impacts of traditional tourism, and this supported the link between VR immersive experience and sustainable VR tourism intentions aroused (Viñals et al., 2021). This also aligns with Mohanty et al. (2020) that VR can motivate travellers to consider virtual travel for pro-environmental reasons.

This study also revealed that VR CAVE and desktop VR deliver comparable results, and this suggested that both can effectively support sustainable VR tourism intentions. However, differences emerged in how social and utilitarian values influence presence and flow across the two systems. For instance, social value significantly influenced presence and flow in desktop VR but not in VR CAVE. This can probably be explained the popularity and accessibility of desktop VR (Beck et al., 2019). By contrast, VR CAVE is generally perceived to provide a more engaging experience (Pellas et al., 2021) and this may explain why utilitarian value only significantly impacted presence and flow in VR CAVE but not in the desktop VR. Unlike entertainment and games where the immersiveness of VR experience can vary greatly between systems and influences customers' experience (Michailidis et al., 2018), sustainable VR tourism uniquely involves environmental and ethical concerns and pro-environmental messages may be sufficiently impactful when delivered through either VR systems.

5.3 Managerial Implications

This study demonstrated the significance of values in driving VR immersion that VR contents can be designed to resonate with tourists' perceived utilitarian, hedonic, and social values. For example, the VR contents should not only provide informative insights of the tourism products but also incorporate emotional resonance and connect with the shared values of customers' peer groups (Feng et al., 2022). Moreover, tourism businesses can prioritize VR immersion through emphasizing the sensation of being physically present within the simulated setting and

the sense of absorption. The study empirically proved the potential of VR experiences in shaping tourists' attitudes towards destinations and towards VR tourism. Tourism businesses and government authorities can leverage this insight to position VR as an alternative means for travelers to explore and connect with destinations (Chang & Chiang, 2022). This try-before-you-travel strategy could effectively reduce carbon emissions from transportation, thereby lessening the severity of global warming, protecting the environment.

More importantly, this study suggested that businesses do not need to solely focus on the most resource-intensive option. Instead, they can explore a range of VR systems and approaches within their resources and affordability. By choosing wisely, businesses can provide meaningful and immersive experiences that align with their business goals, thereby effectively influencing tourists' behaviors and their related sustainable practices. By acting upon these implications, organizations can capitalize on VR's potential to not only enhance customer engagement and satisfaction but also contribute to sustainable tourism practices.

5.4 Limitations and Suggestions for Future Research

Although this research generated insightful findings, it is important to acknowledge several limitations. First, VR contents this research focuses on the two destinations, further studies could replicate this study by examining different destinations and VR contents highlighting other aspects of sustainable tourism (Rasoolimanesh et al., 2023). Second, the cross-sectional method used in this study only captures individuals' VR experiences at a single point in time. Additionally, attitudes toward a destination may be more accurately assessed by measuring changes before and after exposure to the VR experience. Future research could adopt experimental or longitudinal designs to more effectively explore the long-term impact of VR on attitudes and behaviors, as continued pro-environmental engagement contribute to a more sustainable and lasting outcomes (Si et al., 2022). Third, this study compared two VR devices and future research could involve a comparative analysis of various VR systems setups, such as head-mounted devices, tablets, smartphones. This would offer more informed decision-making options for businesses in the tourism industry.

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Appendix A – Measurement Items

Constructs	Items	Sources
Hedonic Value (HV)	HV1 This VR tourism experience was fun. HV2 This VR tourism experience was pleasant. HV3 This VR tourism experience was enjoyable.	(Hsu et al., 2021; Shamim et al., 2024; Wang et al., 2023)
Utilitarian Value (UV)	UV1 This VR tourism experience was helpful to me. UV2 This VR tourism experience was useful to me. UV3 This VR tourism experience was important to me.	
Social Value (SV)	SV1 Having VR tourism can improve my image. SV2 Having VR tourism would make me a good impression on other people. SV3 Having VR tourism can improve relationships with my peers or friends.	
Presence (PRE)	PRE1 I felt like I was actually there in the VR environment. PRE 2 It was as though my true location had shifted into the VR environment. PRE3 I felt as though I was physically present in the VR environment.	(Tussyadiah et al., 2017; Tussyadiah et al., 2018)
Flow (FLO)	FLO1 When I was doing the VR tour, I experienced total involvement in the VR experience. FLO2 I felt like time went by very quickly when I was doing the VR tour. FLO3 I felt that I had an exciting experience during the VR tour. FLO4 The curiosity was uplifted about the tourist attraction/destination while I am doing the VR tour.	
Attitude towards Destination (ATT_D)	ATT_D1 After VR experience, my liking toward the destinations is stronger. ATT_D2 After VR experience, my preference toward the destinations is stronger. ATT_D3 After VR experience, my interest in visiting the destinations is stronger.	(Kyrlitsias et al., 2020; Tussyadiah et al., 2018)
Attitude towards VR Tourism (ATT_VR)	ATT_VR1 This VR tourism experience makes me feel good. ATT_VR2 This VR tourism experience makes me feel less polluted. ATT_VR3 This VR tourism experience makes me feel environmentally responsible.	(Huang, 2023; Talwar et al., 2022)
Sustainable VR Tourism Intention (SVI)	SVI1 I am willing to use VR tourism to protect the environment. SVI2 I plan to join virtual tours instead of traditional travel to reduce carbon footprint. SVI3 I will expend effort on using VR for tourist attractions as an alternative to traditional travel to promote environmental friendliness.	(Talwar et al., 2022)