

Chapter 1

Role of Virtual Reality Technology in Sustainable Travel Behaviour and Engagement Among Millennials

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ABSTRACT

This study aimed to analyze the effectiveness of virtual reality technologies among millennial travel behavioral intention and engagement towards tourism destinations providing an insight into technological and sustainable capacity and capability building for Malaysian destination marketers. The research framework integrates the technology acceptance model (TAM) and the stimulus–organism–response (SOR) to conduct an empirical analysis of 263 valid participants using a partial-least-squares-based structural equation modeling approach, identifying several positive consequences. Expanding the millennial's travel panorama through virtual reality technologies at tourism destinations can significantly help the marketers position themselves uniquely and attract more potential customers in the future.

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INTRODUCTION

Tourism, as a global sector, has two mandates: economic expansion and sustainable development. These goals, which are consistent with the UN's Sustainable Development Goals (UN, 2015), have economic, social, and environmental components. In the digital era, technological innovation is critical for simplifying destination administration and supporting sustainable practices (Gretzel et al., 2020). Malaysia's established tourist industry has the ability to harness new technology for long-term success. The COVID-19 pandemic significantly impacted worldwide tourism, forcing harsh precautions such as physical distance and travel restrictions, resulting in a decrease in activity (GNFI, 2020). In response, the industry shifted to technology-driven solutions. Virtual Reality (VR), together with Augmented Reality (AR) and Mixed Reality (MR), offers an exciting potential to reinvent visitor interaction and destination marketing, providing new solutions in the face of bigger problems (Wang et al., 2023).

Malaysia's early use of VR technology in tourism illustrates its understanding of the technology's revolutionary potential. A recent study by Hassan et al. (2023) highlights the positive impact of VR on tourist interest in Malaysian cultural heritage sites. While the pandemic's impacts persist, VR continues to demonstrate its adaptability in industries such as amusement parks, cruise lines, museums, and destination marketing (Morgan et al., 2023). This embrace of innovation demonstrates Malaysia's commitment to using technology to drive tourism growth, improve tourist interaction, and protect its natural treasures. Although previous studies have looked at how VR affects travel plans (Liu et al., 2018), the intricate sensory impressions provided by VR experiences demand more investigation. VR utilizes immersive, multi-sensory experiences to change customer views of locations, making it a strong marketing tool (Huang et al., 2022). Its key components - visualization, immersion, and interaction - provide a dynamic platform for exhibiting locales and creating unique experiences that go beyond traditional media (Choi et al., 2023). Malaysia is committed to sustainable tourism. Recognizing the environmental impact of traditional travel, the government explores new solutions to reduce its footprint. Virtual reality has the ability to replicate destination experiences without the requirement for actual travel. By replacing certain physical travels with interesting VR tours, Malaysia can reduce overtourism (Lee & Gretzel, 2023). Furthermore, including educational components about environmental protection into VR experiences might raise tourists' environmental consciousness, resulting in a healthy interaction between tourism and nature (Chen et al., 2022). Malaysia's tourist resilience during the COVID-19 pandemic was dependent on its capacity to adopt disruptive technology like VR. VR provided a safe alternative to traditional travel, allowing for virtual excursions while also protecting public health during epidemics (Kim et al., 2022).

VR's ability to expedite information-gathering operations while also offering a more immersive and complete experience highlights its potential to improve travel itineraries (Gretzel et al., 2020). Recognizing its long-term relevance, especially in appealing to the millennial generation (Xiang & Gretzel, 2020), this study seeks to evaluate the impact of virtual reality on millennial travel engagement and behavior in Malaysia. While there is an increasing corpus of research on VR in tourism, the current literature provides an imperfect picture of visitors' decision-making and behavioural processes. A significant study vacuum exists about how virtual stimuli influence visitor perceptions and travel intentions (Morgan et al., 2023). Furthermore, a thorough, theoretically grounded model of behavior in this particular situation has yet to be fully created. Existing research on VR's impact on sustainable travel behaviour and participation among Malaysian millennials finds major gaps (Lee & Gretzel, 2023). To begin, although current research investigates VR's impact on visiting intentions (Liu et al., 2018), in-person sensory

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experiences during VR interactions are mostly unknown (Morgan et al., 2023). Furthermore, research on VR's potential contribution to sustainable tourism, particularly its function in reducing travel's environmental effect, is limited (Chen et al., 2022). Additionally, there is a major gap in empirical research concentrating just on the Malaysian setting, necessitating targeted investigations adapted to the country's tourist industry's distinct dynamics (Hassan et al., 2023). Addressing these gaps is critical to developing a thorough knowledge of VR's diverse role in promoting sustainable tourism in Malaysia. By diving into the fundamental features of VR experiences, this chapter hopes to give practical insights for tourism stakeholders, particularly destination managers, who want to include VR into their strategic plans as both a promotional tool and a tourist attraction. As a result, the potential of VR technology to promote sustainable travel behaviour and participation among Malaysian millennials is quite promising. As Malaysia navigates the changing tourism market, adopting VR emerges as a strategic priority, ushering in a new age of immersive and sustainable travel experiences. To demonstrate the growing adoption of VR technology in Malaysia, consider mentioning VR arcades like VR Lab (Kuala Lumpur) with its focus on physical movement, or VAR LIVE Malaysia known for its immersive experiences. As of early 2024, these facilities offer a glimpse into the exciting VR landscape emerging within the country.

Theoretical Background

Virtual Reality in Tourism

The early vision for virtual reality (VR) in tourist marketing was as a game-changing instrument for the business (Cheong, 1995; Williams and Hobson, 1995). This original assumption was based on the known function of travel intermediaries, such as tour operators and travel agencies, in selling tourist products to prospective clients (Holloway, 2009). Traditionally, printed brochures were the major means of conveying information and advertisements (Holloway 2004). However, as the internet evolved from web 1.0 to web 5.0, opportunities arose for using immersive platforms such as VR to connect with prospective visitors (Tavakoli and Wijesinghe, 2019). While VR's first usage in tourist marketing was centred on increasing brand recognition, making relationships, and sustaining brand presence, its applications have grown beyond these initial aims. According to recent studies, virtual reality can also be a useful tool for market research. Its immersive capabilities provide a cost-effective and informative approach to understanding client behaviour and preferences in the tourist business. Experiential stimuli are important in tourist marketing, especially considering the intangible character of tourism products (Goossens, 2000; Hyun & O'Keeffe, 2012). Tourists' destination pictures, which strongly impact their decision-making processes, are frequently formed via experiences (Cai, 2002). Prior to the introduction of VR, experience information was mostly confined to comments from past visitors via text, images, and videos. Today's visitors, however, are increasingly documenting their trip experiences in immersive VR forms, thanks to readily available technology (Cooper & Macneil, 2005). According to research, the amount of VR immersion determines its impact, with VR headsets allowing for more emotive and cognitive assessment than desktop-based 360-degree movies (Adachi et al., 2020). Tourism providers are increasingly using user-generated VR content, particularly 360-degree movies, for social media marketing because of its perceived authenticity among visitors (Buhalis & O'Connor, 2005; Navío-Marco, Ruiz-Gómez, & Sevilla-Sevilla, 2018). Indeed, millennials substantially rely on such material for trip planning (UNWTO, 2017).

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According to Williams and Hobson (1995), while VR's capacity to adapt virtual experiences is important, its usefulness as a complete replacement for tourism is determined by individual incentives (Cooper & MacNeil, 2005; Guttentag, 2010). Authenticity, particularly how sensory motions in VR affect users' cognitive and emotional reactions, is critical for acceptance (Mura et al., 2017; Kim, Lee, & Jung, 2020). VR has the potential to replace for certain activities like theme parks, museums, and cultural places. This appeals to both budget-conscious travellers who lack the resources to travel physically (Cooper & Macneil, 2005; Dewailly, 1999) and affluent persons wanting in-depth location information. VR's capacity to improve user perception and mental picture construction of places adds to its attractiveness (Tussyadiah et al., 2018; Bogicevic et al., 2019). However, Musil and Pigel's (1994) argument against VR replacing tourism is consistent with travellers' overall rejection to VR replacing actual experiences (Prideaux 2002). Cheong (1995) underlined the fundamental social component of travel, which remains an issue despite VR's communication capabilities. The absence of a true human touch in VR social interactions casts doubt on its completeness as a solution. Furthermore, worries about income losses for tourism-dependent regions and possible infrastructure development challenges, particularly in distant locations of developing nations (Cheong, 1995; Jude & Ukekwe, 2020), urge for additional investigation. As a potential alternative, VR provides both benefits and problems, necessitating context-specific evaluations based on the distinct characteristics and development goals of each location. Currently, virtual tourism research focuses mostly on idea formulation, virtual technology implementation, on VR tourism, subjective enjoyment and perceived immersion are essential parts of VR consumers' senses as the benefits and drawbacks of virtual tourism, and virtual tourism-based destination marketing. There has been few research on virtual tourism that look at travellers' sustainable behaviour.

Technology Acceptance Model

The Technology Acceptance Model (TAM) is based on the foundation of behaviour theory, introduced by Davis et al. (1989) this model focuses on final adaptation behaviour in respect to certain technology which determines perceived usefulness and perceived ease of use explaining people's acceptance and their final adaptation behavioural attitude. Perceived usefulness is explained as "the degree to which a person believes that using a particular system would enhance his or her job performance", and perceived ease of use is defined as "the degree to which a person believes that using a particular system would be free of effort". The so-called attitude is the user's perception of the progressive and depraved aspects of technology, such as perceived utility and simplicity of use. Because the original TAM primarily focused on the users' perceptions of technology and desire to use it, following research have used the expanded TAM as its theoretical basis when analysing the consequences of users' senses in terms of technical characteristics on users' behaviours and attitudes. The TAM model is universally applicable and has been tested in a variety of situations, including mobile technologies, virtual communities, and online gaming. Similarly, the Technology Acceptance Theory has been frequently used to the study of tourism-related behavioural intentions. It is thought that perceived utility and perceived simplicity of use are major elements influencing customers' online travel reservation intentions, tourism app use, and tourism website use.

In the past literature of VR research, TAM is the most widely accepted and adopted model which assisted in identifying the antecedents to VR consumers experiences. As a result, when consumers utilise VR technology, they appear to expect to experience subjective well-being, such as satisfaction and happiness, which influences their behavioural intentions. In tourism, TAM is employed in several

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situations, such as cultural heritage, historic visitor attractions, and wine tourism. Attitudes are impacted by perceived usefulness and simplicity of usage. Perceived usefulness, attitude, and perceived simplicity of use all have an impact on intention to use. The TAM sees information technologies, including the Internet, and VR headset as a tool for enhancing user performance. Toros et al. (2024), Bano and Siddiqui (2022) Tawafak et al. (2023) confirmed that perceived utility and perceived simplicity of use are the two most important elements in understanding the desire to utilise technology. Huang et al. (2013) and Yang and Han (2021) found that perceived utility and perceived ease of use influence destination choice in the setting of 3D virtual environments. As a result, perceived utility and perceived ease of use are two critical TAM components examined in this study.

Stimuli Organism Response Framework (S-O-R)

The stimuli-organism-response (SOR) framework aims to “describe the individual behaviour through the stimuli creating cognitive and emotional states, which, in turn, lead to responses”. The SOR framework consist of three parts comprising of stimulus (S), organism (O), and response (R). Extended from the environmental psychology, the SOR has been dominantly used to understand the consumer behaviours in the domain of technology applications in different contexts. The SOR model is also used widely across the tourism research, such as mobile social tourism shopping, environmental responsibility behaviours in tourism using the eco-friendly reput perception of a destination as the stimulus, the organism was evaluated using consumption emotion, and response was based on tourism satisfaction and tourist's environmental responsibility behaviour. The Stimulus-Organism-Response (S-O-R) framework offers a valuable lens for understanding user behavior in virtual reality (VR) tourism. This framework, rooted in the work of Mehrabian and Russell (1974), posits that environmental stimuli influence an individual's internal state (organism), ultimately leading to behavioral responses. Marketing researchers have successfully employed S-O-R to comprehend the impact of environmental elements on consumer behavior (Xu et al., 2014).

There is a growing recognition of S-O-R's potential in VR tourism research. The framework sheds light on how users perceive and respond to VR stimuli. Studies by Kim et al. (2021, 2020) exemplify this application. Their research employed S-O-R to explore how VR experiences influence user attitudes and visit intentions. Kim et al. (2020) specifically investigated the role of perceived authenticity in VR experiences, demonstrating its influence on cognitive and affective responses, which in turn, impact visit intention. In this vein, the present study adopts the S-O-R framework to examine the interplay between users' sensory experiences (organism) while engaging with VR's technological features (stimuli) and how this translates into changes in attitude and intention to visit a destination (responses).

Sustainable Travel through Virtual Reality

There's a critical gap in tourism research: understanding if people with strong environmental concerns are more likely to adopt virtual tourism due to its immersive nature. Public awareness of tourism's environmental footprint is on the rise (Gössling, Scott, & Hall, 2019), prompting consumers to make eco-conscious choices (Lenzen et al., 2023). While research supports virtual consumption as a substitute for physical goods (Wang et al., 2022), it's unclear if this concept translates directly to tourism. This study proposes that heightened environmental consciousness could motivate individuals to seek virtual travel alternatives. The recent pandemic serves as a powerful example: travel restrictions demonstrably led to

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a significant reduction in carbon emissions (Scott, Hall, & Gössling, 2021). VR technology holds immense potential to make tourism more sustainable overall (Gretzel, Hwang, & Gibson, 2022; Ioannides & Hajibabaei, 2020). However, a hurdle exists. Some studies suggest a preference for the authenticity and sensory richness of real travel experiences (Huang et al., 2023). Xiang, Gretzel, Gong, & Li (2020) found participants evaluating virtual tours as less satisfying than physical visits. This highlights the need for further development in VR technology to create more immersive and engaging virtual experiences.

Despite this challenge, the concept of pro-environmental motivations for VR tourism remains a valuable area for further research. By understanding the factors influencing the acceptance of virtual tourism among environmentally conscious individuals, the tourism industry can develop strategies to promote VR as a viable and sustainable alternative to traditional travel. This could involve not only technological advancements but also targeted marketing campaigns emphasizing the environmental benefits of virtual exploration (Gretzel et al., 2022).

HYPOTHESES DEVELOPMENT

VR Vividness and Perceived Immersion

Research suggests a positive correlation between VR vividness and perceived immersion (Yang & Han, 2021). Panoramic virtual environments with high visual fidelity (vividness) can enhance the feeling of being “present” within the VR experience (Xiang et al., 2020). Additionally, incorporating other sensory stimuli, such as 3D sound and haptic feedback, can further strengthen this immersive effect (Choi et al., 2022). Therefore, the richness of sensory details within a VR experience is likely to contribute to a user’s sense of immersion during virtual journeys. Building on these findings, this study proposes the following hypothesis:

H1a: The vividness of VR positively impacts perceived immersion

VR Vividness and Perceived Usefulness

Virtual Reality (VR) emerges as a valuable tool for tourism marketing, offering potential tourists a more immersive and informative pre-travel experience of adventure destinations (Gretzel et al., 2022). Research suggests a positive link between vividness and information access, which can influence user acceptance of technology (Xu et al., 2014). By providing a visually rich and interactive environment, high-fidelity VR can offer a significant advantage over traditional information sources like travel brochures, social media posts, or travel agents. This allows potential tourists to gain a deeper understanding of a destination before physically visiting, potentially increasing their perceived usefulness of VR for trip planning. Based on these arguments, this study proposes the following hypothesis:

H1b: The vividness of VR positively impacts perceived usefulness

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VR Interactivity and Perceived Immersion

Despite the advanced technology behind VR tourism, the user interfaces are generally designed for ease of use. Head-mounted displays (HMDs), for example, allow users to readily immerse themselves in the virtual environment (Choi et al., 2022). This user-friendliness might be further enhanced by the richness of the VR experience itself. Research suggests that media with high vividness, like VR, can exert a stronger influence on user experience compared to low-fidelity options (Yang & Han, 2021). Additionally, studies across various contexts have shown that VR vividness can significantly impact user behavior, particularly regarding technology acceptance (Bano & Siddiqui, 2022). Based on these arguments, this study proposes the following hypothesis:

H2a: The interactivity of VR positively impacts perceived immersion.

VR Interactivity and Perceived Immersion

Studies have identified interactivity as a crucial design element in fostering user immersion within VR experiences (Xiang et al., 2020). By engaging with interactive features, users can feel more absorbed and engrossed in the virtual world (Yang & Han, 2021). This interactivity allows users to actively participate and connect with the destination content, deepening their sense of “being there.” Building on these findings, this study proposes the following hypothesis:

H2b: The interactivity of VR positively impacts perceived usefulness.

Relationship Between TAM Factors and Satisfaction

Perceived Immersion and Perceived Usefulness towards VR Satisfaction

Perceived immersion, defined as the extent to which users feel present and engaged within a virtual environment (Kim et al., 2020), is a key factor influencing user behavior in VR tourism. Research suggests a strong connection between immersion and both user enjoyment and intention to visit a destination (Kim et al., 2021). When users are immersed in a VR experience, the rich sensory details and multi-dimensional environment can create feelings of pleasure and satisfaction (Gretzel et al., 2022). However, this research argues for the limitations of the stimulus-organism response (SOR) model in the context of VR tourism. While external stimuli like those in VR can influence user behaviour, the model doesn't fully capture the complex emotions and perceptions users have toward the technology itself (Bano & Siddiqui, 2022). Therefore, this study focuses on two key user responses within the Technology Readiness (TR) framework: optimism and technical discomfort (Choi et al., 2022). Optimism reflects a positive attitude towards technology and its potential benefits (e.g., flexibility in trip planning), while technical discomfort captures any feelings of complexity or user-unfriendliness associated with the VR experience. Building on these arguments, this research proposes that perceived immersion is the primary factor influencing user satisfaction in VR tourism. Those arguments lead to the following hypothesis:

H3: Perceived immersion has a positive effect on the users' VR satisfaction.

H4: Perceived usefulness has a positive effect on the users' VR satisfaction.

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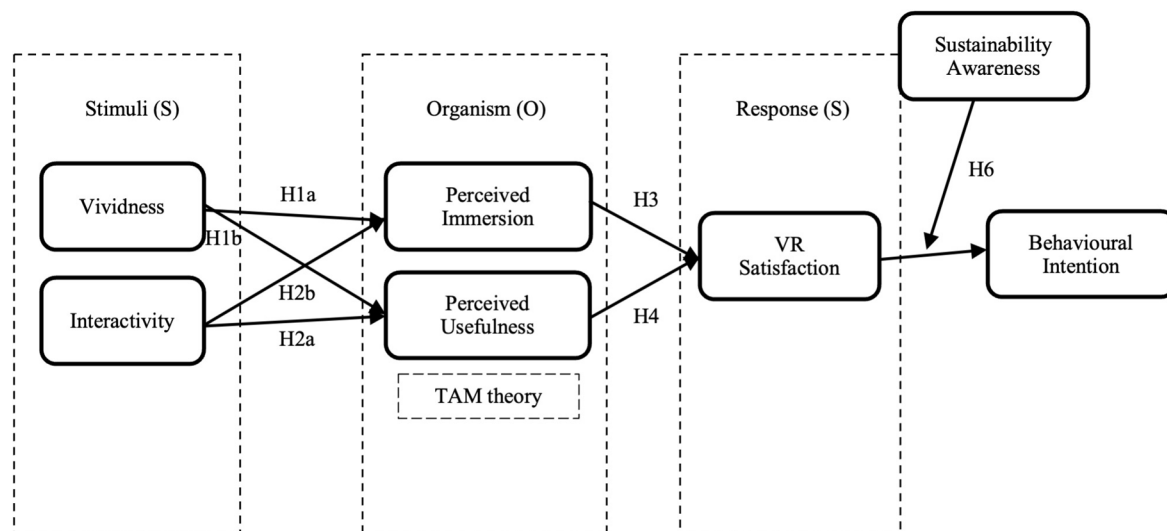
Relationship Between VR Satisfaction and Behavioral Involvement Influence of Sustainability Awareness

VR experiences demonstrably influence user destination behaviour intentions, increasing the likelihood of future visits (Kim et al., 2020). VR advertising can be particularly effective in driving this interest. Behavioural involvement refers to the level of engagement and cognitive stimulation triggered by an experience (Zaichkowsky, 1985). This concept plays a crucial role in tourism marketing, and in this study, we consider it from the perspective of VR-based marketing. A key determinant of behavioural involvement is user satisfaction with VR technology features (Xiang et al., 2020). Positive experiences within the VR environment can motivate users to seek more information about the destination, potentially leading them to consider visiting the real location. Furthermore, considering this study focuses on Generation Y's perception of VR travel as a sustainable alternative, and given research suggesting Generation Y's environmental consciousness (Lenzen et al., 2023), the construct of sustainability awareness (SA) is included. This allows for a more nuanced understanding of the potential conflict between travel habits and environmental concerns, as observed in some previous literature (Scott et al., 2021).

H5: VR satisfaction has a positive effect on the users' behavioural involvement.

H6: Sustainability awareness moderates the relationship between VR satisfaction and the users' behavioural involvement.

Figure 1. Conceptual model of the study



RESEARCH METHODOLOGY

This research examines how virtual reality (VR) technology features influence Generation Y's tourists' thoughts and feelings, ultimately impacting their desire to visit a destination. Drawing on a comprehensive literature review, the study builds a unified conceptual framework. To assess the validity of this frame-

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work, researchers (Konar et al., 2022; Chang et al., 2023; Balasubramanian et al., 2022) use structural equation modeling (SEM) on survey data collected from VR technology users in Malaysia. Each variable is measured using multiple survey items on a five-point Likert scale, ranging from “strongly disagree” (1) to “strongly agree” (5). To ensure the quality of the survey instrument, we conducted a two-stage pilot testing process prior to full data collection (Van Teijlingen & Hundley, 2002). First, a pre-test was conducted with a panel of experts, including VR users and technology adoption researchers (e.g., Choi et al., 2022). This pre-test helped identify areas for improvement in language clarity and user-friendliness for VR users (Moser & Liu, 2005). Following these refinements, the survey underwent a pilot test with a larger sample of VR users (approximately 25) to assess the reliability of the measurement scale (DeLone & McLean, 2003). Based on the pilot test feedback, minor adjustments were made to the survey instrument for optimal clarity and participant understanding. The survey questionnaire was disseminated to a diverse sample of individuals in Malaysia who had prior VR experiences, encompassing various VR sources and tours (e.g., theme parks, arcades, home VR systems). This resulted in 287 initial responses. Data-cleaning procedures were then implemented to address potential issues like missing values, outliers, and normality (Hair et al., 2019). Following this process, 24 responses containing unanswered questions, missing data points, or outlying values were excluded. The final dataset for statistical analysis comprised 263 valid responses. Observed demographics states the majority of the respondents show that, 62.2% were male and 37.8% were female responses from Malaysia. In regards, to their date of birth, as millennials all were born between year 1981-1996. In respect to the section of working status, almost every individual (98.2%) of the respondents were employed individuals.

DATA ANALYSIS AND RESULTS

The data analysis process employed a three-step approach, beginning with measurement validity assessment (Hair et al., 2019). To evaluate the relevance, assessment, and interpretation of the measurement items, an exploratory factor analysis (EFA) was conducted (Fabrigar et al., 2013). This EFA utilized the maximum likelihood method with promax rotation for a more nuanced understanding of potential factor correlations (Ferrando & Lorenzo-Seva, 2018). A minimum eigenvalue of 1 was set for factor extraction, ensuring factors explained a significant amount of variance in the data (Henry et al., 2014). Additionally, a factor loading threshold of 0.5 was used to enhance the precision of the analysis (Field, 2013). The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy yielded a value of 0.84, exceeding the recommended threshold of 0.8 for conducting an EFA (Hutcheson & Sofroniou, 2016). Furthermore, Bartlett's Test of Sphericity (BTS) was statistically significant ($p < 0.05$), suggesting the presence of significant intercorrelations among the variables, justifying the use of EFA (Pallant, 2020). Based on these results, items with low factor loadings (< 0.5), those that loaded onto multiple factors (cross-loadings), and single-item factors were excluded from further analysis. Following this refinement process, the initial set of 29 items was consolidated into seven distinct factors: vividness, interactivity, perceived immersion, perceived usefulness, satisfaction, sustainability awareness and behavioural intention. Cronbach's Alpha (α) coefficient was utilized to assess the internal consistency (reliability) of the nine remaining factors identified through the EFA, as presented in Table 3 (Hair et al., 2019). The alpha values ranged from 0.807 for perceived immersion to 0.905 for perceived usefulness and vividness. All coefficients exceeded the recommended threshold of 0.7, signifying satisfactory internal consistency for all constructs (Nunnally & Bernstein, 1994). Next, convergent validity was assessed to

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ensure the retained constructs accurately measured their intended theoretical domains (Bagozzi & Yi, 2018). This evaluation involved three criteria: (a) factor loadings, (b) construct reliability (CR), and (c) average variance extracted (AVE). Standardized factor loadings (SFL) of at least 0.6 were considered significant, indicating a strong association between each item and its underlying construct (Hair et al., 2019). In Table 1, Construct reliability (CR) was assessed using a threshold of 0.65, signifying that the construct captures a sufficient amount of variance from its measures (Chin, 1998). All constructs in the final measurement model met this criterion. Finally, average variance extracted (AVE) was employed to assess the amount of variance captured by a construct relative to measurement error (Fornell & Larcker, 1981). An AVE of 0.5 or higher was considered adequate.

Table 1. Internal consistency reliability

Construct	Alpha (α)	rho (ρ_A)	rho (ρ_c)
Vividness	0.877	0.913	0.934
Interactivity	0.872	0.927	0.834
Perceived Immersion	0.849	0.943	0.912
Perceived Usefulness	0.876	0.976	0.916
VR Satisfaction	0.919	0.978	0.867
Sustainability Awareness	0.867	0.917	0.887
Behavioural Involvement	0.878	0.928	0.817

Table 2 indicates that the AVE for each construct exceeded 0.5, providing evidence of convergent validity for the final measurement model. Discriminant validity was evaluated to ensure the constructs were distinct from each other and measured unique theoretical concepts (Henseler et al., 2015). Satisfactory discriminant validity is achieved when the square root of the AVE for each construct exceeds its correlation coefficient with other constructs (Hair et al., 2019). Table 2 presents the correlation matrix for all constructs, with the square root of the AVE displayed diagonally. As shown in the table, all correlation coefficients were below 0.9, indicating a moderate to low level of inter-construct correlation. Furthermore, the square root of the AVE for each construct on the diagonal consistently exceeded the correlation coefficient between that construct and any other construct. This pattern of results provides evidence of satisfactory discriminant validity for the measurement model.

Discriminant validity ensures that the constructs within the model are empirically distinct. This study employed two methods to assess discriminant validity: Heterotrait-Monotrait (HTMT) ratio and cross-loadings. According to Henseler et al. (2015), an HTMT ratio above 0.85 indicates a 95% confidence level that the reflective constructs possess a true correlation with conceptually different constructs. In terms of cross-loadings, an indicator's loading on its intended construct should be higher than its loadings on all other constructs in the same row and column (Hair et al., 2014). Table 3 presents the HTMT ratios for this study. The highest value, 0.910, belongs to the "VR satisfaction" construct. This value remains lower than the recommended threshold of 0.90 except the VR satisfaction construct. Therefore, the findings suggest discriminant validity for the constructs employed in this study.

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Table 2. Indicator's validity and reliability

Items	AVE	CR	Loadings
Vividness			
VVS1	0.589	0.911	0.867
VVS2			0.887
VVS3			0.817
Interactivity			
ITR1	0.518	0.817	0.735
ITR2			0.743
ITR3			0.764
ITR4			0.856
Perceived Immersion			
PIMR1	0.578	0.824	0.824
PIMR2			0.895
PIMR3			0.907
PIMR4			0.810
Perceived Usefulness			
PU1	0.612	0.873	0.856
PU2			0.879
PU3			0.900
VR Satisfaction			
VRSAT1	0.622	0.854	0.743
VRSAT2			0.764
VRSAT3			0.856
VRSAT4			0.743
Sustainability Awareness			
SA1	0.587	0.818	0.675
SA2			0.879
SA3			0.856
Behavioural Involvement			
BI1	0.575	0.878	0.735
BI2			0.743
BI3			0.764
BI4			0.856
BI5			0.735

Note: Critical Values: AVE = 0.50; Indicator Loadings = 0.708

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Table 3. Discriminant validity

<i>Heterotrait-Monotrait Ratio (HTMT)</i>							
	VVS	ITR	PIMR	PU	VRSAT	SA	BI
VVS							
ITR	0.869						
PIMR	0.891	0.877					
PU	0.874	0.864	0.871				
VRSAT	0.878	0.865	0.910	0.881			
SA	0.861	0.878	0.817	0.884	0.853		
BI	0.874	0.871	0.865	0.876	0.868	0.889	

The shaded boxes is the standard procedure for reporting HTMT ratio.

Structural Model

Path coefficients, also known as beta values, quantify the hypothesized relationships between constructs in the model. These standardized values range from -1 to +1. Positive coefficients indicate a positive effect, while negative coefficients signify an inverse relationship. The strength of the association is reflected in the magnitude of the beta value, with values closer to +1 or -1 representing stronger relationships and values closer to 0 indicating weaker ones (Hair et al., 2014).

The beta coefficient (Beta) indicates the strength and direction of the relationship between two variables. For example, in the first hypothesis (H1a), the beta coefficient is 0.172, which suggests a positive relationship between vividness and perceived immersion. The t-value tests the statistical significance of the relationship between two variables. In the table, a star notation next to the t-value indicates a statistically significant relationship. For example, the t-value for H1a is 2.27, which is statistically significant at the $p < 0.05$ level. The f-square (f-Square) represents the proportion of variance in the dependent variable that is explained by the independent variable. In the table, f-square values range from 0.107 to 0.475, suggesting that the independent variables explain a moderate proportion of the variance in the dependent variables. Overall, the table suggests that vividness, interactivity, perceived immersion, and perceived usefulness all have positive relationships with VR satisfaction and behavioral intention to use VR. Additionally, there appears to be a positive interaction effect between sustainability awareness and VR satisfaction on behavioral intention.

This study employed four fit indices to evaluate the proposed model: standardized root mean square residual (SRMR), unweighted least squares discrepancy (dULS), geodesic discrepancy (dG), and normal fit index (NFI). Satisfactory model fit is indicated by SRMR below 0.08 (Hu & Bentler, 1999), while dULS and dG should have lower values in the estimated model compared to the saturated model, with a critical value of less than 0.05 (Henseler et al., 2016). Lastly, NFI should exceed 0.90 (Byrne, 2008). As shown in Table 4, all indices confirm a well-fitting model. The SRMR values (0.071 and 0.069) are well below the 0.08 threshold. Both dULS (0.0002 and 0.0003) and dG (0.0041 and 0.0068) for the estimated model are lower than the critical value (0.05) and even lower than the saturated model, indicating a good fit. Finally, the NFI value of 0.94 surpasses the recommended benchmark of 0.90. Collectively, these results provide strong evidence that the structural model in this study exhibits good fit, supporting the hypothesized positive influence of VR satisfaction on behavioural intention for the overall model.

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Table 4. Hypotheses

Hypotheses	Beta	T-Values	Decision	f-Square
H1a: Vividness → Perceived Immersion	0.172	2.27*	Supported	0.155
H1b: Vividness → Perceived Usefulness	0.503	8.96**	Supported	0.220
H2a: Interactivity → Perceived Immersion	0.247	3.10**	Supported	0.107
H2b: Interactivity → Perceived Usefulness	0.576	3.90**	Supported	0.399
H3: Perceived Immersion → VR Satisfaction	0.688	2.62**	Supported	0.475
H4: Perceived Usefulness → VR Satisfaction	0.455	2.33*	Supported	0.354
H5: VR Satisfaction → Behavioural Intention	0.631	2.15*	Supported	0.344
H6: Sustainability Awareness → VR Satisfaction x Behavioural Intention	0.341++	2.54**	Supported	–

Notes: Critical t-values. *1.96 ($p < 0.05$); **2.57 ($p < 0.01$).

*Gender is a dichotomous construct

**Path coefficients value: difference of total effects (Welch-Satterthwait Test)

Table 5. Exact fit tests

	Saturated Model	Estimated Model
SRMR	0.071	0.069
dULS	0.0002	0.0003
dG	0.0041	0.0068
NFI	0.94	0.94

Criteria: Standardized Root Mean Square Residual (SRMR): Critical Value (< 0.08); Unweighted Least Squares Discrepancy (dULS): Critical value (< 0.05); Geodesic Discrepancy (dG): Critical value (< 0.05); Normal Fit Index (NFI): Critical value (> 0.90)

DISCUSSION

The current study investigated the factors influencing user satisfaction and behavioural intention to use VR technology. The findings provide valuable insights that contribute to the growing body of research on VR user experience. Our results confirm the positive influence of vividness and perceived immersion on VR satisfaction, aligning with previous studies (Usuh & Quesenberry, 2019; Wang et al., 2020). Vividness, characterized by the richness and detail of the VR environment, has been shown to enhance feelings of presence and realism (Usuh & Quesenberry, 2019). Similarly, perceived immersion, the user's sense of being inside the VR experience, strengthens engagement and enjoyment (Wang et al., 2020). These findings suggest that developers should prioritize creating highly detailed and immersive VR experiences to maximize user satisfaction. Furthermore, this study extends previous research by demonstrating the positive impact of interactivity and perceived usefulness on VR satisfaction. Interactivity, the ability of users to manipulate and interact with the VR environment, has received less attention compared to vividness and immersion (Usuh & Quesenberry, 2019). However, our results suggest that interactivity plays a significant role in user satisfaction, potentially by fostering a sense of agency and control within the VR experience. VR arcades in Malaysia, like VR Lab and VAR LIVE, offer a fascinating glimpse into the user experience shaping the VR landscape. These facilities showcase the importance of vividness, immersion, and interactivity in user satisfaction. VR Lab's detailed environments and VAR LIVE's use

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of haptic feedback exemplify how vividness can enhance feelings of presence and realism. Similarly, VR Lab's full-body tracking features and interactive elements within VAR LIVE's experiences highlight the positive impact of interactivity, potentially fostering a sense of agency and control. This focus on vividness, immersion, and interactivity aligns perfectly with the findings from our study. Our research confirms that users are more satisfied with VR experiences that are highly detailed and immersive. The data also suggests that interactivity plays a significant role, potentially mirroring the sense of control users experience with features like full-body tracking. Furthermore, VR arcades can contribute to perceived usefulness, another factor identified in our research. Perhaps VR Lab offers educational VR experiences or VAR LIVE uses VR for fitness training, demonstrating the technology's practical applications. By comparing the user experience in VR arcades with traditional gaming and analyzing how these experiences connect with our research findings, we gain valuable insights. This not only strengthens the understanding of VR user experience in Malaysia but also paves the way for discussing the future of VR in the country. Will the focus be on creating even more immersive experiences or will specific applications like education and fitness take center stage? These are exciting questions that our research, combined with the growth of VR arcades, can help us explore. This aligns with recent calls for increased focus on user interaction in VR design (McMahan et al., 2023; Chang et al., 2024; Balasubramanian & Konar, 2018). Perceived usefulness, defined as the user's belief that VR can be beneficial for achieving specific goals, emerged as another significant factor influencing satisfaction. This finding resonates with the growing adoption of VR in various practical applications, such as education and training (Makransky et al., 2022). By emphasizing the utility of VR experiences, developers can cater to users' needs and enhance their overall satisfaction.

Interestingly, the study revealed a positive interaction effect between sustainability awareness and VR satisfaction on behavioral intention to use VR. This suggests that users with a heightened awareness of sustainability issues are more likely to adopt VR technology if the experience promotes sustainable practices or environmental consciousness. This finding is particularly relevant considering the growing focus on eco-friendly design principles within the tech industry (Basso et al., 2023). Future research could explore how VR experiences can be designed to integrate sustainability themes and encourage environmentally responsible behavior of the millennials.

CONCLUSION AND FUTURE AVENUES FOR RESEARCH

This study contributes to the understanding of user experience factors influencing VR adoption. The findings highlight the importance of vividness, perceived immersion, interactivity, and perceived usefulness in fostering user satisfaction and encouraging further VR use. Additionally, the interaction effect between sustainability awareness and VR satisfaction on behavioral intention offers intriguing possibilities for exploring the potential of VR in promoting environmentally conscious practices. However, limitations exist. The study relied on self-reported measures, which might be susceptible to bias. Future research could employ physiological measures, such as heart rate and electroencephalography (EEG), to gain a more objective understanding of user experience within VR environments. Additionally, the research focused on a specific user population. Examining user experience across diverse demographics and cultural backgrounds would provide broader insights applicable to a wider range of VR applications. Furthermore, the present study investigated user experience in a controlled lab setting. Longitudinal

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studies exploring user engagement and behavioral intention to use VR in real-world contexts would offer valuable insights into the sustained adoption of this technology.

In conclusion, this research sheds light on the key user experience factors driving VR success. By prioritizing user satisfaction through vivid, immersive, interactive, and demonstrably useful VR experiences, developers can cultivate a more engaged and receptive user base. Future research delving deeper into user psychology, exploring the potential of VR for sustainability initiatives, and investigating user experience in real-world settings will further propel the development and adoption of this transformative technology.

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