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Exploring the Impact of Virtual Reality on Tourists' Pro-Sustainable Behaviors in Heritage Tourism

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Abstract

Although the rise of Virtual Reality (VR) technology has brought new opportunities to tourism experiences and marketing, limited research has explored how VR technology affects tourists' pro-sustainable behaviors in heritage tourism research. To address this research gap, this study constructs a theoretical model by integrating the technology acceptance model (TAM) framework to explore the relationship among perceived ease of use (PEU), perceived usefulness (PUS), awe, attitude, and pro-sustainable behavior of tourists. Through the analysis of 304 valid questionnaires, this study found that in the heritage tourism experience presented by VR, PEU and PUS positively influence awe and attitude. Furthermore, awe positively affects attitude and pro-sustainable behaviors. However, PUS has no effect on tourists' pro-sustainable behaviors. This study expands the theoretical framework of TAM and the related research on awe in heritage tourism presented by VR, providing valuable practical insights for heritage managers in the adoption of immersive technology.

Keywords: virtual reality; heritage tourism; sustainability; technology acceptance model

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1. Introduction

Virtual Reality (VR) is an important immersive technology for tourism [1,2]. Recent studies have expounded on the role that VR plays in tourism and marketing of tourist destinations from different theories and research methods. For instance, research suggests that VR's technological innovativeness can positively influence visitor enjoyment [2]. Teng et al. also found that consumers' personal innovativeness is perceived through usefulness, attitude, and desire, and then positively influences VR tourism intention [3]. These studies show that VR tourism can significantly enhance tourists' travel intentions and promote destinations. Furthermore, scholars have further confirmed through qualitative research and experimental design that VR tourism experiences can significantly influence tourists' travel intentions [4–6]. However, these studies have overlooked the influence of VR on tourists' sustainable behaviors.

To fill this research gap, this study applied the technology acceptance model (TAM) theoretical model to address the above research question. TAM is a classic theory of technological acceptance first proposed by Davis [7]. This theory holds that the two prerequisite factors influencing an individual's attitude and behavior are perceived usefulness (PUS) and perceived ease of use (PEU) in technology experience. In tourism research, TAM has been widely applied to new technologies that present tourism experiences [8,9]. Among them, scholars mainly enhance the theoretical and model interpretation development of the TAM model by adding new variables based on the TAM theory (e.g., [10]). Therefore, the current research introduces awe and pro-sustainable behavior to evaluate tourists' environmental protection behaviors based on VR tourism experiences by integrating TAM models.

In tourism research, awe has always been an important concept for evaluating tourists' emotional responses [11,12]. Awe makes tourists feel their own insignificance, thereby shifting their attention to external affairs and influencing their behaviors [13]. For example, in religious tourism, scholars have pointed out that awe is an important leading variable that can affect the pro-environmental behaviors of religious tourists [14]. Similarly, studies have suggested that awe can enable tourists to perceive a smaller self and make them feel more closely connected to nature [12]. Although scholars have pointed out that awe is an important factor that can affect tourists' sustainable behaviors, its role in immersive technologies, such as VR, and whether it can affect tourists' behaviors has received limited attention from scholars [15]. Pro-sustainable behavior is defined by scholars as persistent and repetitive actions taken for the purpose of changing, benefiting, or minimizing the impact of human beings on the environment [16]. Pro-sustainable behavior has been confirmed by previous empirical studies to be an appropriate variable for evaluating the sustainable behavior of tourists [17,18]. Therefore, this study holds that pro-sustainable behavior is an appropriate variable to understand tourists' responses in VR-presented heritage tourism.

In sum, to fill the above research gaps, the purpose of this study is to explore the relationship among PEU, PUS, awe, attitude, and pro-sustainable behavior based on VR travel experiences. Furthermore, three main research questions (RQ) have been raised at present regarding VR-presented heritage tourism: RQ1: Will PEU and PUS significantly influence tourists' awe? RQ2: Will PEU and PUS significantly affect tourist attitude and pro-sustainable behavior? RQ3: Will awe significantly affect tourist attitude and pro-sustainable behavior? The potential contributions of the current research are as follows. This study expands the TAM theoretical model in the context of VR-presented heritage tourism. Furthermore, this study tests the relationship between awe, attitude, and pro-sustainable behavior, providing managers with solid theoretical findings. Finally, the conclusions arising from the current research are conducive to managers improving VR products to better promote the sustainable development of heritage tourism.

2. Literature Review

2.1. TAM Theory

As noted above, TAM posits that two primary factors influencing an individual's attitude and intention regarding the adoption and use of technology are perceived usefulness (PUS) and perceived ease of use (PEU) [7]. PUS refers to an individual's subjective evaluation of whether the application of technology can bring practical benefits [7]. PEU relates to the assessment of the simplicity and user-friendliness of the technology [7]. When an individual perceives that a technology is easy to master and can meet their needs, they are more inclined to adopt it [19]. Scholars have applied the TAM model to tourism research to explore user acceptance and related influences of emerging technologies in the tourism

industry [20,21]. While expanding the model, researchers have continuously incorporated new external variables to enhance TAM's explanatory power. For instance, Cai et al. reported that the personification of hotel voice assistants, along with PUS and PEU, positively impacts customers' usage intentions and word-of-mouth [22]. Thus, the widespread application of TAM in studying new technology adoption provides an appropriate theoretical foundation for this study.

2.2. VR Tourism

Virtual Reality (VR) is an interactive, digitally generated medium that offers users immersive and multi-sensory experiences by simulating real or unreal scenarios [23,24]. Kim and Hall defined VR tourism as the exploration of travel information and the experience of travel-related activities through VR devices by watching 3D 360-degree videos and holographic images [23].

Existing literature broadly discusses the complementary and substitutive effects of VR on actual tourism activities from a macro perspective [25,26]. For example, Guttentag, leveraging the characteristics of VR in simulating real situations, highlighted its significant potential in heritage preservation [27]. Some research has also explored tourists' acceptance of VR and the impact of VR experiences on tourists' destination image perception and travel intentions. Schiopu et al. demonstrated that the ease of use, usefulness, and substitutability of VR positively influence VR adoption intentions in the tourism industry [19]. Atzeni et al. further revealed the relationship between VR authenticity and satisfaction and destination visitation intentions, discussing the mediating role of cognitive and emotional responses [28]. However, despite some studies focusing on VR's influence on pre-travel decision-making, few have examined the broader impacts of VR on tourists' sustainable behaviors. To fill this research gap, this study focuses on the impact of VR tourism on tourists' sustainable behaviors.

2.3. Sustainable Tourism and Awe

Sustainable tourism, which aims to enhance economic opportunities and quality of life while preserving the natural and cultural heritage of destinations, is a key goal of tourism development [29]. Studies have studied sustainable tourism from the perspectives of various stakeholders. Some literature analyzes the roles and responsibilities of tourism enterprises [30] and local communities in sustainable tourism [31]. Other research has focused on tourists' behaviors and mechanisms in sustainable tourism. For example, studies have confirmed the positive effects of individual traits such as altruistic values [17] and education levels [16], as well as emotional factors like nostalgia [32], on tourists' pro-sustainable behaviors.

Among studies involving emotional factors, awe is regarded as an emotion closely related to sustainable tourism experiences [33]. Awe is an emotional response that can be evoked by exposure to stimuli considered greater than the self, accompanied by a need for cognitive adaptation [13,34]. In the tourism industry, scholars have verified that destinations such as religious sites [35], forest parks [36], and marine protected areas [37] can induce awe in tourists, thereby positively influencing their pro-environmental behaviors. However, scholars deem that sustainable tourist behavior should cover economic, environmental, cultural, and social aspects, with pro-environmental behavior being part of pro-sustainable behavior [38]. Landon et al. noted that pro-sustainable behavior reflects intentions related to reducing environmental impact, consuming local goods and services, and being willing to sacrifice time and money for sustainable options [17].

Awe in tourism can make travelers feel small and respectful, shifting their focus from themselves to external matters and prompting altruistic behavior [13,39]. Zhao et al.

indicated that awe could lead to prosocial behavior, including pro-sustainable behavior, by making individuals more willing to temporarily sacrifice personal interests for social benefits [40]. Studies have consequently argued that awe can increase tourists' attention to destination sustainability and encourage pro-sustainable behavior at the destination [12,41]. Therefore, this study posits that tourists may experience awe during heritage tourism, which could impact subsequent behaviors. However, these assumptions require further empirical research for clarification.

2.4. Hypothesis Development

In this study, TAM is applied to virtual tourism. The PEU is defined as tourists' perception of how easy or difficult it is to master VR equipment, while PUS is defined as the degree to which tourists believe using VR helps improve the efficiency of travel information acquisition and enhances their travel experience [42]. In the tourism field, awe is regarded as a positive emotion that transcends the self, which occurs when tourists encounter natural landscapes, cultural heritage resources, or activities that exceed their cognitive understanding, creating a sense of wonder and surprise [13,36]. Shiota et al. indicated that tourists' perception and recognition of landscapes during travel can easily trigger feelings of awe [43]. Lu et al. suggested that the perception of vast natural environments is more likely to evoke awe in tourists [33], and similar results were obtained by Wang and Lu [41] and Alrawadieh et al. [44] in the contexts of wildlife destinations and heritage sites. Consequently, this study posits that in heritage tourism, when tourists have a thorough understanding of travel information and engage in in-depth destination experiences, their awe emotion is likely to be evoked.

VR technology combines Virtual Reality with tourism through modern information and communication technologies, offering a flexible, convenient, all-encompassing, and immersive travel experience [26,45]. Loy et al. reported that VR space tourism can evoke a sense of awe in participants [46]. Zhang et al. confirmed that online VR exhibitions of communist heritage can inspire awe in tourists [47]. Wu and Lai investigated how the creativity and authenticity of short video content about destinations affect viewers' awe emotions [48]. Therefore, this study suggests that when tourists enhance their travel experience through VR technology, the PEU and usefulness of VR can evoke awe in tourists.

H1: PEU positively affects tourist awe in VR tourism.

H2: PUS positively affects tourist awe in VR tourism.

Research on awe has often focused on its impact as a positive emotion [49,50]. In tourism research, it has been found that positive emotions can enhance tourist behaviors [50]. As a positive emotion, awe is believed to improve tourist satisfaction or subjective well-being. On the other hand, awe comprises two characteristics: perceived vastness and a need for accommodation. These can change tourists' perceptions and attitudes toward the external environment and trigger corresponding behavioral responses. In a study of sustainable tourism, Lu et al. identified that awe positively influences tourists' attitudes [33]. Wu and Lai also indicated that in destination short-video viewing, awe positively affects attitudes toward the short videos and, in turn, attitudes toward the destination [48]. Thus, the following research hypothesis is proposed.

H3: Awe positively affects attitude in VR tourism.

Numerous studies have demonstrated the strong connection between PUS, PEU, and attitudes. In tourism, Wang et al. suggested that the PUS and PEU of short video applica-

tions can influence users' attitudes toward using such applications for travel planning [51]. The tourism industry also utilizes VR technology to enhance tourists' attitudes toward specific locations. Teng et al. confirmed the positive impact of PEU and PUS on attitudes toward VR tourism [2]. Similar conclusions were drawn by Sancho-Esper et al. [20]. In addition, Raj et al. focused on the elderly as a study group and found that PUS and PEU positively influence the elderly's attitudes toward adopting VR technology for religious tourism [52]. Additionally, some scholars believe that the use of VR in tourism can enhance tourists' attitudes or satisfaction toward specific locations [28]. Therefore, the present study hypothesizes that in heritage tourism presented through VR, when tourists perceive VR as easy to use and that it provides authentic and rich interactive experiences, they will develop positive attitudes. Consequently, this study proposes the following hypotheses:

H4: PEU positively affects attitude.

H5: PUS positively affects attitude.

Previous studies have mainly used TAM to examine tourists' VR usage intentions in tourism. For example, Zhang and Xiong verified that PEU, PUS, and attitude have a direct positive impact on users' intentions to participate in VR tourism [53]. Some studies have focused on the impact of VR experiences on users' visits to actual tourist destinations. For instance, Rasul et al. showed that PEU and PUS of VR experiences can attract potential tourists to related destinations [54]. Although empirical research on the relationship between VR perceptions and pro-sustainable behavior is limited, several studies have confirmed the effects of PUS and PEU of VR tourism experiences, as well as attitudes, on tourists' participation in tourism activities and their word-of-mouth and willingness to recommend destinations [20,55]. Thus, the current research believes that PEU and PUS can influence tourists' pro-sustainable behaviors in VR experiences.

H6: Attitude positively affects pro-sustainable behavior in VR tourism.

H7: PEU positively affects pro-sustainable behavior in VR tourism.

H8: PUS positively affects pro-sustainable behavior in VR tourism.

All research hypotheses are presented in Figure 1.

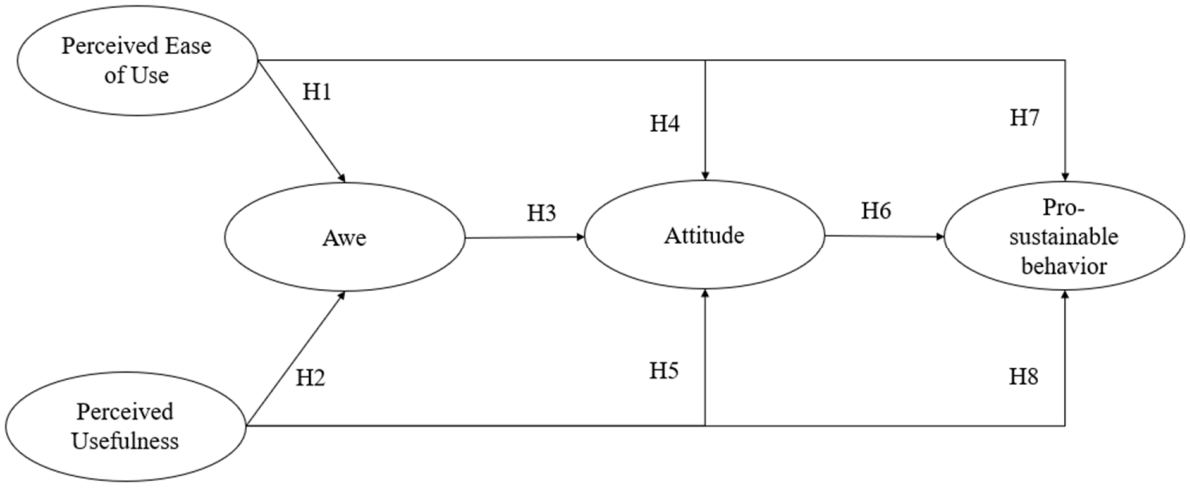

Figure 1. Research model.

3. Research Method

3.1. Study Site

To evaluate the current research model, this study chose the Palace Museum in Beijing, China, as the heritage research location. To begin with, the Palace Museum is an internationally renowned historical and cultural heritage site that was inscribed on the UNESCO World Heritage List in 1987. The Palace Museum, one of the world's most visited heritage sites, received 516,600 visitors during the 2024 National Day holiday period, with daily visitor caps strictly implemented [56]. To enhance the travel experience of tourists, the Palace Museum has introduced many immersive technologies to improve the travel experience of tourists [57]. In these immersive experiences, tourists can learn about the history, culture, and other stories behind the scenic spots, ultimately enhancing their travel experience. Based on the above points, this study considered that the Palace Museum in Beijing is a valuable representative site of the combination of heritage destinations and VR technology. Figure 2 presents a photo of the Palace Museum in Beijing.

Figure 2. Study site (the Palace Museum). Source: photo taken by authors.

3.2. Questionnaire Design

The survey in this study consists of three main sections. The first part contains an introduction to the research, providing background to the study, and a screening question. The first part of the survey aims to clearly inform the study participants of the purpose and background of the research, thereby reducing the potential for common method bias. A screening question was also used to ensure selection of the appropriate sample population: Have you had VR travel experience at the Palace Museum in Beijing within the past three months? Those who answered 'no' were regarded as invalid questionnaires.

The second part of the survey contains several measurable items for five variables. For measuring PEU, this study refers to Zhu et al. [10]. To measure PUS, this study uses Wang et al. [58]. For examining awe, questions are used from Zhao et al. [15]. For measuring attitude, the work of Yang et al. [59] is used. For measuring pro-sustainable behavior, this study utilizes the questions of Salinero et al. [38]. All measurable items of the survey were presented in a 7-point Likert scale, with 1 to 7 representing from "strongly disagree" to "strongly agree", respectively.

The last part of the survey asked questions regarding the socio-demographic information of the participants, including gender, age, educational background, and monthly income. Since the current target group is Chinese tourists, the translation and proofreading of the survey were completed by two tourism professionals who are proficient in both English and Chinese. To evaluate the content of the questionnaire, in May 2025, a pilot test was undertaken, inviting 30 participants, all of whom clearly indicated that they understood the content of the survey. Therefore, the current survey was not further modified, with the data of the 30 pre-surveyed individuals being excluded from the main data analysis.

3.3. Data Collection

This study adopts an online questionnaire as the data collection method. Online questionnaires have several advantages. First, online questionnaires can provide a high response rate and a wide range of participant samples [60]. Secondly, in recent research on museum and immersive technology experiences, online questionnaires have become well-regarded as an effective way to investigate museums based on VR tourism presentations [28]. Third, they are an effective way of conducting research in heritage spaces that may otherwise be too congested or crowded to effectively undertake face-to-face interviews, or if respondents are time-scarce. Therefore, the current research adopts online surveys for data collection. The current research collects data through the sample service of Tencent Questionnaire, one of the largest data collection platforms in China. The users of Tencent Questionnaire are all appropriately registered to ensure the authenticity of the questionnaires. Reliability and validity based on the sample service of Tencent Questionnaire have been recognized by many leading SSCI-listed journals [57]. Data collection was completed from 8 May to 14 May 2025. A total of 400 participants completed the questionnaire. However, some invalid questionnaires were removed for not having experienced the VR experience of the Palace Museum in Beijing within the past three months. Consequently, a total of 304 valid questionnaires were used for the current data analysis.

4. Results

This study adopts partial least squares-structural equation modeling (PLS-SEM) analysis mainly based on the following two points. Firstly, PLS-SEM is suitable for small sample data. Secondly, PLS-SEM has no mandatory requirements for whether the data conforms to the normal distribution [61]. Therefore, SmartPLS version 3 software is used for data analysis in the current study.

4.1. Sample Background

A total of 304 participants participated in the current study. By gender, male participants comprise 49.7% of participants and females 50.3%. The monthly income of the group with the highest income ranges from CNY 4001 to CNY 6000. Undergraduates represent the highest proportion of respondents, accounting for 59.5% of all participants. The age group with the highest proportion is 18–25 years old, accounting for 29.6% of respondents. Table 1 presents detailed information from 304 participants.

Table 1. Respondent background (n = 304).

Gender	Frequency	Percentage
Male	151	49.7
Female	153	50.3

Table 1. *Cont.*

Salary monthly		
CNY 4000 or CNY 4000 below	57	18.8
CNY 4001–6000	83	27.3
CNY 6001–8000	51	16.8
CNY 8001–10,000	53	17.4
CNY 10,001–15,000	43	14.1
Over CNY 15,000	17	5.6
Education		
Primary school	1	0.3
Middle school	12	3.9
Junior college	85	28
Undergraduate	181	59.5
Graduate	25	8.2
Age		
18–25	90	29.6
26–30	66	21.7
31–35	60	19.7
36–40	47	15.5
41–45	26	8.6
46–50	10	3.3
Over 50	5	1.6

4.2. Model Evaluation

To evaluate the reliability and validity of the current research model, bootstrapping with 5000 samples was used for data analysis. This study evaluated factor loading, Cronbach's Alpha, composite validity, average variance extracted (AVE), and heterotrait/monotrait ratio (HTMT) values. Table 2 shows that factor loading is higher than 0.7. In Table 3, both Cronbach's Alpha and composite validity are higher than 0.7, and both AVEs are higher than 0.5 [61]. Finally, all HTMT values were lower than 0.9 [61]. Therefore, the current research model has achieved acceptable reliability and validity.

Table 2. Measurable items of the model.

Perceived Ease of Use (PEU)	**Factor Loading**
PEU1: Learning to use VR technology is easy in tourism experience.	0.837
PEU2: It is easy to navigate VR technology in tourism experience.	0.839
PEU3: The use of VR technology is flexible in tourism experience.	0.854
Perceived Usefulness (PUS)	
PUS-1: I think VR technology can give me a deeper understanding of products or services.	0.893
PUS-2: I think VR technology can save me time in making travel plans.	0.814
PUS-3: I think VR technology can provide me with valuable information.	0.859
AWE	
AWE-1: When I experienced the VR technology towards destination, what I watched gave me a deep sense of vastness.	0.861
AWE-2: When I experienced the VR technology towards destination, I felt small in front of what I watched.	0.853
AWE-3: When I experienced the VR technology towards destination, what I saw was surprising and difficult to understand.	0.718

Table 2. *Cont.*

Perceived Ease of Use (PEU)	**Factor Loading**
Attitude (AT)	
AT-1: I think that engaging in pro-environmental behavior is enjoyable.	0.759
AT-2: I think that engaging in pro-environmental behavior is beneficial.	0.810
AT-3: I think that engaging in pro-environmental behavior is important.	0.804
AT-4: I think that engaging in pro-environmental behavior is worthwhile.	0.826
AT-5: I think that engaging in pro-environmental behavior is compatible with my lifestyle.	0.799
AT-6: I think that engaging in pro-environmental behavior is satisfying.	0.801
Pro-sustainable behavior (PSB)	
PSB-1: After experiencing VR technology, I perform green practices to protect the environment on my trips	0.868
PSB-2: After experiencing VR technology, I usually report to the destination administration of any environmental pollution I see when on my trips	0.707
PSB-3: After experiencing VR technology, I act responsibly to protect the destination's environment on my trips	0.882

Table 3. Reliability and validity of the model.

	Cronbach's Alpha	**CR**	**AVE**	**AT**	**Awe**	**PEU**	**PUS**	**PSB**
AT	0.887	0.914	0.640					
AWE	0.746	0.853	0.662	0.768				
PEU	0.803	0.881	0.711	0.741	0.755			
PUS	0.817	0.891	0.732	0.880	0.849	0.801		
PSB	0.762	0.862	0.677	0.866	0.834	0.708	0.766	

4.3. Hypothesis Testing

Before conducting hypothesis testing, this study evaluated for potential common method bias. Based on Kock's suggestion, the VIF index was an appropriate index to evaluate the common method bias of the PLS-SEM model [62]. All VIF values were lower than 3.3. Therefore, the data of the current model will not be affected by CMB. Through bootstrapping analysis with 5000 samples, all hypotheses were established except that PUS had no significant effect on pro-sustainable behavior (0.082^{ns}). PEU positively affects awe (0.286 ***), attitude (0.221 ***), and pro-sustainable behavior (0.165 **). PUS positively affects awe (0.494 ***) and attitude (0.488 ***). Awe positively influences attitude (0.173 **). Attitude positively influences pro-sustainable behavior (0.567 ***). To evaluate the predictability of the model, the current study evaluated R-squares, and all R-squares exceeded 0.2. The R-square for attitude is 0.62, awe is 0.512, and pro-sustainable behavior is 0.565. Thus, this model achieved acceptable prediction [61]. Figure 3 and Table 4 present the results of PLS-SEM analysis.

Table 4. Results of hypothesis development.

	Path Coefficient	***p* Values**	**Results**
H1: PEU -> Awe	0.286 ***	0.000	Accepted
H2: PUS -> Awe	0.494 ***	0.000	Accepted
H3: Awe -> AT	0.173 **	0.006	Accepted
H4: PEU -> AT	0.221 ***	0.000	Accepted
H5: PUS -> AT	0.488 ***	0.000	Accepted
H6: AT -> PSB	0.567 ***	0.000	Accepted
H7: PEU -> PSB	0.165 **	0.004	Accepted
H8: PUS -> PSB	0.082 ^{ns}	0.308	Rejected

Note: *p*-value < 0.001 = ***; *p*-value < 0.01 = **; ns = not significant.

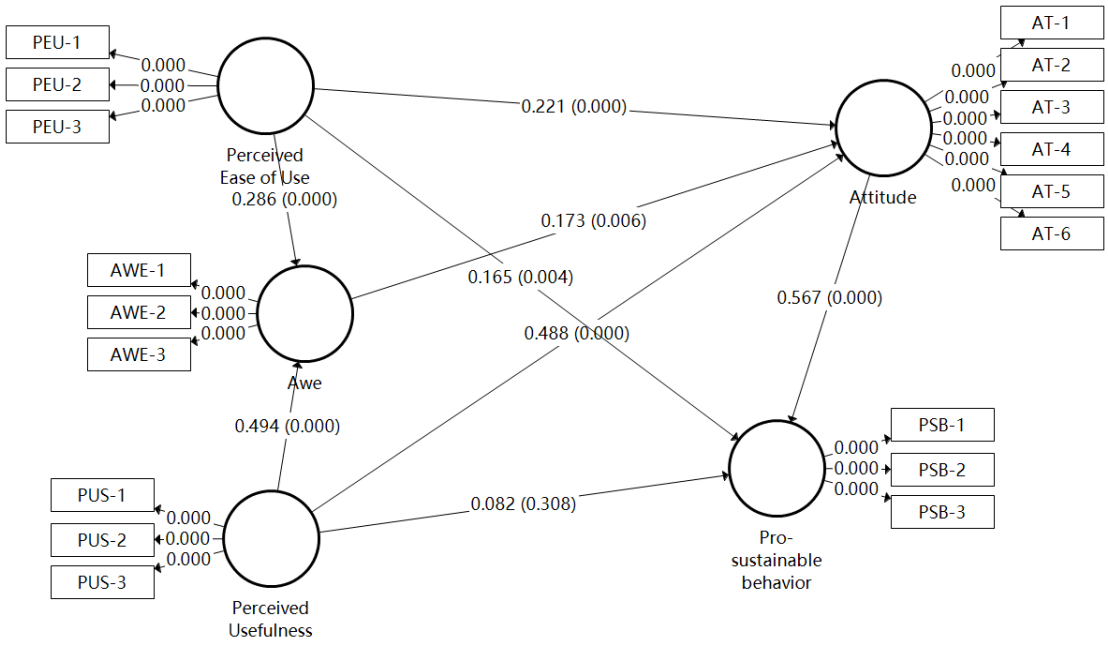

Figure 3. Results of Smart-PLS analysis.

5. Discussion

This study found that visitors' awe responded positively when they received PEU and PUS. Awe stems from the amazement and surprise that tourists have toward heritage, landscapes, or other features that they understand as being beyond their cognition [13,36]. The profound history and cultural heritage of the Palace Museum in Beijing enable tourists to gain perceptions beyond their own experiences presented through VR. That is, VR experiences enrich and enhance the original experience of the Palace Museum in Beijing. Therefore, VR experiences can enhance awe. Given that visitors were able to master the use of VR easily and conveniently, the perception of the visitor experience was enabled by PEU and PUS [42]. In VR experiences, tourists can not only have a clearer understanding of the Palace Museum presented by VR but also receive corresponding voice explanations. These VR experiences further enhance the usefulness of VR technology and help explain why the awe of current tourists will significantly increase after they acquire PEU and PUS.

Secondly, this study found that when tourists experience PUS, PEU, and awe, their attitudes are positively influenced. VR-presented tourism features ease of use, innovative technology, and multi-distance experience. Therefore, when current tourists experienced the VR devices, their attitudes received positive feedback due to the simplicity and convenience of the VR as well as the rich and diverse tourism experiences. For awe, this perception stems from the excitement and novelty beyond its own experience. Significantly, for heritage management, VR technology not only retains some of the original features of the scenic spots but also adds more distant and rich content presentation on this basis. Therefore, this explains why when tourists are experiencing VR, their PUS and PEU, as well as a sense of awe, can significantly influence their attitudes. Furthermore, the research found that PEU has a positive impact on tourists' pro-sustainable behavior, but PUS has no significant impact on tourists' pro-sustainable behavior. One possible explanation for PUS is that the usefulness of VR experiences needs to be constantly updated, as tourists encounter many new channels every day in learning about major heritage attractions such as the Palace Museum and the corresponding heritage conservation and management needs of the site. Therefore, tourists' exposure to conservation is not limited to VR devices,

and the acquisition of diverse information from other sources may affect tourists' judgment on the usefulness of VR perception and thereby influence their pro-sustainable behaviors.

Finally, the study also explored the relationship between awe, attitude, and pro-sustainable behavior. Studies have suggested that in tourism, a sense of awe can make travelers feel their own insignificance, shifting their attention away from themselves to external things, and prompt them to engage in altruistic behaviors [13]. Scholars have noted that a sense of awe can even make individuals more willing to temporarily sacrifice personal interests for social interests, thereby influencing tourists' pro-environmental behaviors [39], at least in the short term. Therefore, the sense of awe that tourists feel when experiencing the Palace Museum through VR may be further enhanced with the support of specific multi-dimensional VR content. In VR experiences, visitors can have a greater sense of distance. For instance, through the presentation and expansion of the sensory system, VR technology can enrich visitors' auditory, visual, and tactile sensory experiences, thereby further enhancing the perception of awe. Therefore, this explains why awe actively acts in the environmental behavior of tourists.

5.1. Theoretical Contributions

This study is the first to contribute to the concept of awe in VR tourism. Previous studies have pointed out that awe is an emotional response [34] and can make travelers feel their own insignificance compared with nature [13]. The concept of awe has been verified by different research in a range of environments including religious sites [35], forest parks [36], and marine protected areas [37], but it has received limited attention in immersive tourism experiences like VR, even though it is of growing importance in heritage management and marketing. Therefore, the first contribution of the current research lies in expanding the concept of awe in VR tourism.

Secondly, the current study extends the TAM theoretical model by testing the relationship between PEU, PUS, and awe. For the TAM theoretical model, many scholars have previously expounded that this theory is a suitable theoretical model for explaining the impact of technology on tourists (e.g., [22]). Our research once again confirms that in the VR environment, PEU and usefulness can positively influence attitudes [2]. However, this study introduces the concept of awe. Therefore, this study shows that when tourists enhance their travel experience through VR technology, their perception of the PUS and PEU of VR can arouse feelings of awe. VR technology can combine reality with tourism, providing flexible, convenient, all-around, and immersive tourism experiences [26,45]. Therefore, the current study confirms that PEU and PUS are suitable prerequisites for exploring their impact on awe.

Finally, this study contributes to the growing literature on the role of immersive technology research in sustainability, particularly in a heritage context. In previous research, attitudes toward tourists and pro-sustainable behavior toward awe were primarily focused on offline tourism experiences. For instance, studies found that awe can positively influence tourists' pro-sustainable behaviors [40]. In environmental protection, when tourists gain awe, it also prompts them to engage in pro-environmental behaviors [39]. However, these studies did not focus on presenting how tourist environmental protection behaviors are affected by VR technology. Therefore, the current research expands pro-sustainable behaviors in the context of VR technology.

5.2. Practical Contributions

This study also provides several practical contributions to museums and heritage site management. First, it found that PEU and PUS significantly affect tourists' awe and attitude. For managers, there is a need to constantly ensure that the functions of VR devices

are convenient for users and that they have a sufficient understanding of the devices. For instance, when designing VR tourism experiences, managers can improve the VR product experience based on consumers of different age groups. For teenagers and children, managers can incorporate some knowledge quizzes, lottery games, and other environments to enhance the usability and awareness of VR devices. For senior tourists or those with less understanding of such devices, managers can set some VR products to have an easier user mode, making their operation more convenient and simpler, thereby enhancing the usefulness and other features of VR, which then positively impacts tourists' attitudes.

Secondly, this study notes that after tourists gained a sense of awe, there were positive changes in their attitudes and intentions for environmental protection. For managers, especially for more fragile heritage sites, this sense of awe emphasizes the profound emotional responses that tourists experience and which may then be harnessed to influence tourists to engage in behaviors that help conserve the heritage site.

Finally, the study found that PUS had no significant impact on tourists' pro-sustainable behavior. From the perspective of PUS, managers need to pay greater attention to whether the introduction of tourism product services in VR experiences can help tourists save time and provide valuable information. For instance, managers need to constantly ensure that the historical interpretations of VR products are relevant to the audience, especially considering their prior experiences and knowledge levels. This is because when outdated information presentation and promotional methods are presented, they may not be deeply attracted by it. Therefore, managers need to ensure that the content and presentation of VR remain relevant. Additionally, in terms of the planning and route design of VR-based tourists' experiences, managers need to introduce appropriate navigation or AI-assisted systems to enhance the tourist experience, thereby improving tourists' environmental protection behaviors.

6. Conclusions

The current research, through the empirical research analysis results, examines in the VR heritage tourism context, how the perceived ease of use and perceived usefulness of VR influence tourists' awe, attitude, and pro-sustainable behavior. Data analysis shows that all the research hypotheses are significantly valid, except that perceived usefulness has no significant impact on pro-sustainable behavior. Despite its contributions, this study still has some limitations that future research can address. First, this study only focuses on the Palace Museum in Beijing. Future research can apply the current research model to other heritage attractions and sites presented by VR. Secondly, the participants in the current study did not distinguish the differences in attitudes and behaviors towards VR experiences among participants of different age groups. The adoption of multi-group analysis, as well as different levels of prior knowledge, may therefore be relevant for further comparison. Finally, the current research adopted the collection method of online questionnaires. In future research, offline face-to-face interviews as well as observation-based approaches can be usefully applied to enhance the conclusions and generalization of survey-based research.

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