Chapter 6
User Acceptance of 720° Virtual Tour Systems for Online Museum Experiences: Effects of Immersion, Interaction, and Personal Innovativeness

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Abstract As a type of immersive visual media technology, 720° virtual tours are developing rapidly and gaining popularity in various industries, such as online museum experiences. However, there is limited research on the user acceptance of 720° virtual tours. By reviewing the literature on technology acceptance theories, this study explores the factors affecting users' acceptance of 720° virtual tour systems based on the Unified Theory of Acceptance and the Use of Technology (UTAUT). We conducted a survey study and collected 150 responses. The analysis showed consistent results with UTAUT and confirmed the positive impacts of performance expectancy, effort expectancy, social influence, and facilitating conditions on behavioral intention. In addition, our study contributes to the understanding of technology acceptance of 720° virtual tour systems by introducing three constructs related to the technology and user characteristics: immersion, interaction, and personal innovativeness. Based on the research results, we propose some practical suggestions for the design and development of 720° virtual tour systems for future online museum experiences.

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6.1 Introduction

Virtual Reality (VR) allows immersive experiences and supports rich and natural interactions with the virtual environment (Violante et al. 2019; Nanjappan et al. 2018; Lu et al. 2023) When using VR, users are isolated from the real world and are able to interact with computer-generated, virtual content, usually through a head-mounted display (HMD) and hand-held controllers or hand gestures (Yu et al. 2018; Shi et al. 2023; Yu et al. 2021; Wang et al. 2023). As an emerging visual media technology, 720° virtual tour systems bring immersive experiences to users by providing a 720° viewing perspective of the digital content (Domański et al. 2017). It supports both immersive devices such as HMDs and 2D displays such as PCs and mobile devices. Compared to VR systems that often require significant resources and technical support in the design, development, and operations, a 720° virtual tour system is an alternative that shows a simpler development approach, lower creation cost, and wider application scenarios (Mabrook and Singer 2019; Wang and Wang 2021). 720° virtual tour systems have been increasingly applied in remote museum experiences (Kalving et al. 2022) and online education (Rupp et al. 2019).

Museums in China have been actively adopting 720° technologies for online experiences. A recent study showed hundreds of exhibitions curated and published online in China, most of which are based on panoramic technologies (Wang and Wang 2021). These authors discussed the advantages of 720° technologies in online virtual museum experiences, which can be summarized in four key aspects: (1) fast production regardless of the complexity of the exhibition layout, (2) flexible and customizable digital content creation, (3) effective copyright protection through watermarking and domain access control, and (4) rich presentation forms of exhibits and multimedia support. Researchers also identified that compared to onsite visits, 720° virtual tours enable the display of the museum exhibits with information fusion (Shan et al. 2021) and break the limitations of storage and time (Zhang and Xue 2023). In addition, social functions such as likes and sharing are afforded by 720° virtual tour systems deployed on the web, which contribute to users' effective social learning of cultural heritage (Li and Xiao 2021; Zhang and Xue 2023).

The potential benefits of a technology depend heavily on users' willingness to use it (Vallade et al. 2021). Previous work has shown efforts in the design, development, and evaluation of the usability of 720° virtual tour systems, especially in the field of education (Rupp et al. 2019; Sultan et al. 2019; Violante et al. 2019). However, user acceptance of 720° virtual tour systems is still not well understood. Many theories have been proposed to study technology acceptance and use, such as the Technology Acceptance Model (TAM) (Davis 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). These theories and models have been applied and tested in various domains, usually with extended constructs. This chapter presents a study that attempts to fill the research gap by investigating the user acceptance of 720° virtual tour systems, with a particular focus on the theoretical frameworks for the use of immersive technologies.

This study aims to identify the main factors that affect the user acceptance of 720° virtual tour systems for online museum experiences. Considering the technology and user characteristics, we extended the UTAUT with three new constructs: immersion, interaction, and personal innovativeness. We collected 150 survey responses and tested the proposed research model. The results showed that users' behavioral intention is positively influenced by performance expectancy, effort expectancy, social influence, and facilitating conditions, as indicated in UTAUT. In addition, immersion and interaction positively influence performance expectancy and effort expectancy; personal innovativeness positively influences users' performance expectancy. Based on the results, we discuss implications and provide suggestions for the design of 720° virtual tour systems for online museum experiences.

The following sections are structured as follows. We first present a background of online museum experiences, 720° technologies, and the theoretical basis of technology acceptance. Next, we present our research model and introduce the research hypotheses. After explaining the data collection methods, we present the analysis results and show the validation of the hypotheses. The results and implications are then discussed, and a conclusion is drawn.

6.2 Background

6.2.1 Online Museum Experiences: From 2D to 3D

An online museum, sometimes referred to as a virtual museum, is defined as "a means to establish access, context, and outreach by using information technology" (Schweibenz 1998). It is an extension of the physical museum that presents content in any digital form, such as photographs of museum exhibits and 3D reconstructed collections.

Various forms of media have been used for online museum experiences. In the early days, online museum experiences primarily used images and sometimes videos to showcase museum exhibits, accompanied by text descriptions. These images and videos are often shown on 2D displays, presenting museum collections with a particular focus on the visual details. A recent growing trend in online museum experiences is to show collections in 3D (Perry et al. 2017), including reconstructions of the museum artifacts and the space around them.

Previous work has explored approaches to presenting immersive museum experiences. For example, (Bruno et al. 2010) adopted a large screen display with 3D glasses so that visitors can obtain stereoscopic views of the archaeological findings. Haydar et al. (2011) adopted a similar projection-based approach with a large screen display, a head-mounted viewing device, and hand-held interaction devices for interactive visualizations of underwater archaeology. However, these are often included as part of a physical exhibition set up, but not for online museum experiences.

Researchers have also explored ways to present 3D museum collections through web-based approaches. For example, (Wojciechowski et al. 2004) introduced the ARCO system that supported the use of VR and Augmented Reality (AR) technologies to view reconstructed cultural objects. Specifically, they adopted AR markers and see-through HMDs for the triggering of the 3D models of museum collections and allowed users to use a standard mouse and keyboard to interact with the web interface menus and use other inputs such as touchscreens and physical marker manipulations to interact with the augmented 3D representations (Liarokapis 2007). The web-based approach is free from geographic constraints and offers the opportunity for a wider audience to visit museums online. However, although the use of novel technologies such as VR and AR can enable 3D views, these technologies have not been widely accepted nor applied in current online museum experiences. The main challenge lies in the need for specialized hardware, such as head-mounted displays.

720° virtual tour systems, on the other hand, have gained significant popularity in China. During the pandemic, the Ministry of Culture and Tourism of the People's Republic of China has jointly initiated 50 online exhibitions with numerous art galleries and museums nationwide (Ministry of Culture and Tourism of the People's Republic of China 2020), most of which adopted 720° technologies. These online exhibitions balance visual quality and accessibility, enabling the presentation of high-resolution virtual tours on standard devices such as personal computers and smartphones. While the exhibitions may not be as immersive and may offer limited interactivity compared to VR experiences, they effectively address the limitations of devices and ensure engagement with the public audience.

6.2.2 Virtual Reality and 720° Technologies

Immersive visual media technologies can simulate the surroundings of the museum objects and users, supporting them to feel a sense of being there in the 3D virtual environment (Ch'ng et al. 2020; Liu et al. 2021). In addition, interactions with digital content can be supported in these systems (Bruno et al. 2010). The sense of immersion and the interactive features differentiate VR and 720° virtual tour systems from online museum experiences based on traditional media and 2D displays.

Although 720° technologies are sometimes included in or referred to as VR technologies, we would like to make a distinction here. As defined by Brooks (1999), a VR experience is '*any in which the user is effectively immersed in a responsive virtual world*'. Specifically, the visual display is a completely simulated virtual world that blocks out the real world, and a VR system provides real-time rendering of the virtual environment based on users' dynamic control of their viewpoints and locations. Although web-based 720° virtual tours on PCs and mobile devices present immersive panoramas, given that users are not in a completely simulated virtual world, they are not true VR experiences.

720° technologies also differ from VR in content creation and the degree of control. Unlike VR, which may present artificial environments from 3D modeling, 720° virtual tour systems are usually based on panoramic views created from images of real physical spaces. Hu et al. (2017) described a technical framework of 3D virtual museum creation based on hybrid 3D data, which included panoramic images collected from laser scanning and some 3D modeling data to complement the scene. Based on high-resolution photos, this approach preserves visual details to a great extent. Achieving such high visual fidelity in VR requires a greater amount of data for 3D reconstruction. Recent advancements in hardware and software allow even faster creation of 720° panoramas. Tools such as PTGui[1] and Pano2VR[2] among others were used in some recent works (Cao et al. 2022; Shan et al. 2021; Wang and Wang 2021). These tools support panoramic image editing and stitching, as well as path planning for virtual navigation. By stitching images to create a panorama and integrating multiple panoramas into a path, a panoramic scene can be displayed, allowing users to move around and change viewing perspectives both horizontally and vertically (Violante et al. 2019). While 360° videos typically display a view from a fixed camera spot (such as in (Cai et al. 2018; Hayes and Yoo 2018; Kalving et al. 2022)), 720° systems allow users to travel between different teleport points. However, the control over navigation in 720° virtual tour systems is not as free as in VR. Users can only navigate among the preset camera positions, making continuous movements within the panoramic scene unsupported.

The web-based approach of 720° virtual tour systems makes online museum experiences accessible from a variety of devices, including mobile devices, personal computers, as well as VR HMDs. Accessing it using HMDs was found to have suffered from the lack of personal contact and missing multimodal contextual cues (Kalving et al. 2022). Still, thanks to the ubiquity of personal devices, 720° virtual tour systems are currently widely used in online museum experiences, such as historical sites (Li and Huang 2022; Li and Xiao 2021), indoor exhibition halls in museums (Hu et al. 2017; Shan et al. 2021), and outdoor archaeological sites (Sun et al. 2020). Extensive research has been conducted to show the design and implementation of panoramic virtual tour systems (Hayes and Yoo 2018; Hu et al. 2017; Lee and Tsai 2015). Nevertheless, the acceptance of technology and users' intention to use the systems are still not understood.

6.2.3 Technology Acceptance Theories

The theoretical studies of technology acceptance have a long history and there were models and theories being proposed from different perspectives. Examples include the Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1977), the Motivational Model (MM) (Davis et al. 1992), the Theory of Planned Behavior (TPB) (Ajzen 1985), the Technology Acceptance Model (TAM) (Davis 1989) and TAM 2 (Venkatesh and Davis 2000), the Combined TAM and TPB (C-TAM-TPB) (Taylor

[1] https://ptgui.com/.

[2] https://ggnome.com/pano2vr/.

and Todd 1995), the Social Cognitive Theory (SCT) (Heffernan 1988), the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003), and the UTAUT 2 (Venkatesh et al. 2012). In this section, we briefly review the key theories that have been widely adopted in existing works.

In the 1970s, (Fishbein and Ajzen 1977) proposed the Theory of Reasoned Action (TRA) and identified the effects of attitude and subjective norms on the intention to use. The TRA model has been widely considered as a general model for understanding the behavioral intention and users' behavior (Aleassa et al. 2011; Bhattacherjee and Lin 2015; Nor et al. 2008; Shih and Fang 2006). TRA assumes that each individual's use intention of a new technology is a personal rational process, without considering external influences. However, the interference of external factors can not be excluded or underestimated in practical applications, which limits the explanatory power of TRA for use behavior.

In the 1980s, (Davis 1989) proposed the Technology Acceptance Model (TAM), focusing on the relationship between attitude and intention in TRA. This model shows that individuals' attitude toward use is determined by two factors: perceived usefulness and perceived ease of use; their attitude and perceived usefulness jointly determine users' behavioral intention. TAM is one of the most known and applied theories of technology acceptance. In the 2000s, (Venkatesh and Davis 2000) revised TAM and proposed TAM 2. The revised model considered subjective norms in TRA, which were not considered in TAM. It included factors related to social influence and cognitive instrumental process and identified them as determinants of perceived usefulness. TAM 2 showed that perceived usefulness is the most important impact that influences behavioral intention (Venkatesh 2000).

Considering the effects of external variables and various theoretical models proposed for technology acceptance, (Venkatesh et al. 2003) proposed the Unified Theory of Acceptance and Use of Technology (UTAUT). Compared with previous models such as TAM, UTAUT demonstrated higher prediction power of users' behavioral intention (Lee et al. 2003; Wedlock and Trahan 2019). In addition, (Venkatesh et al. 2003) confirmed through empirical studies that behavioral intention has a direct effect on users' use behavior. UTAUT summarizes the factors that influence individual behavior into four core constructs: performance expectancy, effort expectancy, social influence, and facilitating conditions. In addition, four moderating variables were found to have significant effects: age, gender, experience, and voluntariness of use. In the 2010s, (Venkatesh et al. 2012) extended it to UTAUT 2 by adding three variables to the original UTAUT model: hedonic motivation, price value, and habit. It was found to have improved the variance explained in behavioral intention and use behavior.

Previous work has investigated the technology acceptance of immersive technologies in various domains, such as cultural heritage and tourism (Ch'ng et al. 2020; Haugstvedt and Krogstie 2012; Jung et al. 2018; Li et al. 2018; tom Dieck and Jung 2018), education and training (Barrett et al. 2023; Monteiro et al. 2022; Shen et al. 2019), and exercising (Xu et al. 2023b). Many of these studies extended the TAM or UTAUT by considering features of the technology and user characteristics. For example, (Barrett et al. 2023) considered the effects of immersion, interaction, and imagination on the intention to use VR for Chinese language education; users' personal innovativeness was considered in their use of AR applications for urban heritage tourism (tom Dieck and Jung 2018; Monteiro et al. 2022) studied the role of self-efficacy in the use of VR for practical learning. These factors were found to have a significant impact on the perceived usefulness (or performance expectancy) and perceived ease of use (or effort expectancy). While 720° virtual tour systems share similar technology characteristics, the impact of immersion and interaction on its acceptance has not been examined. Understanding the effects of technology features and user characteristics not only provides useful insights into the use of the technology but also helps guide the design of the information systems and user experiences.

6.3 Research Methodology

6.3.1 Research Model

In this study, we aim to explore the factors influencing user acceptance of 720° virtual tour systems for online museum experiences. After reviewing the related work, we propose our research model based on the UTAUT model (see Fig. 6.1). We did not choose UTAUT 2 because the 720° virtual tour systems for online museum experiences are usually free of charge, and it is not a system developed for habitual use. Thus, price value and habit are not relevant to the context of our study. In addition, previous work showed that the positive effects of hedonic motivation on behavioral intention were significant for immersive VR systems using a VR HMD (an HTC Vive) but not significant for desktop VR systems (Huang 2020). Given that 720° virtual tour systems are most likely to be viewed on PC and mobile devices, we opted to situate our study on the existing work and extend the original UTAUT model. In the next section, we explain the proposed hypotheses in detail.

6.3.2 Hypotheses

Our proposed research model includes nine constructs: Interaction (IN), Immersion (IM), Performance Expectancy (PE), Personal Innovativeness (PI), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Behavioral Intention (BI), and Use Behavior (UB).

Immersion and Interaction. Immersion and interaction are the key features of immersive visual media technologies. Immersion is defined as the sense that users feel as if they are in a virtual environment when using a virtual technology (Witmer and Singer 1998). In contrast to the static image displays, 720° virtual tour systems enable real-time interactions that are instantly responsive to users' inputs. Previous research

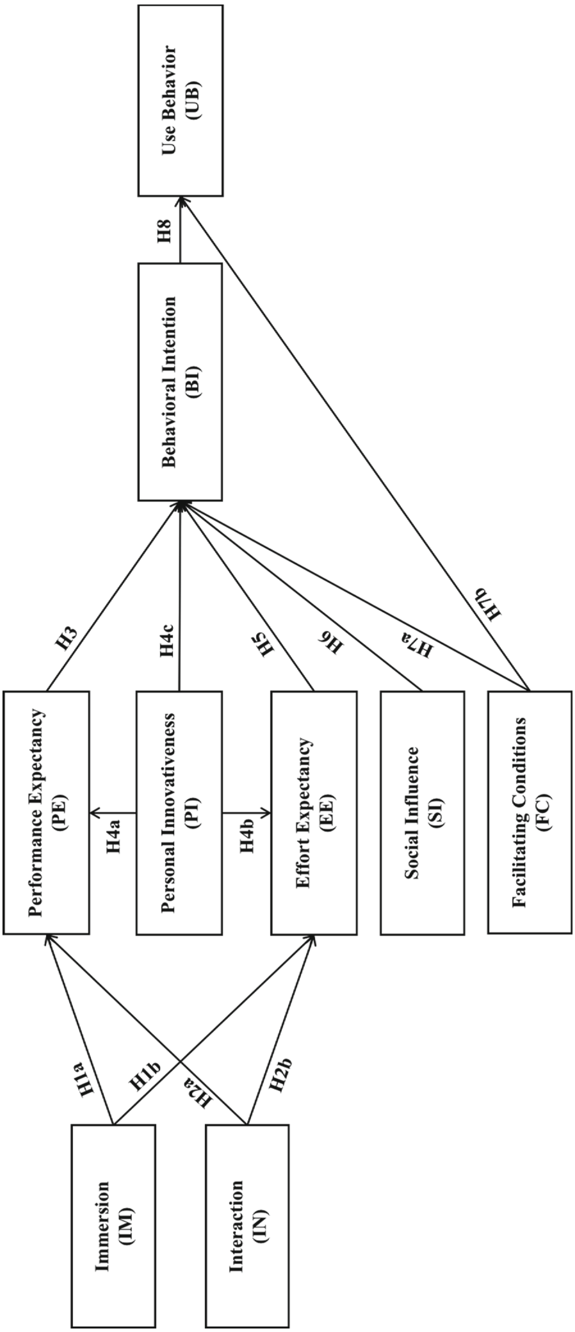

Fig. 6.1 Proposed research model

has examined the role of immersion and interaction on users' perceived usefulness and perceived ease of use (Barrett et al. 2023). These two factors correspond to the performance expectancy and effort expectancy constructs in UTAUT. Given the positive relationship shown in the literature, we hypothesize that

H1a: Immersion in 720° virtual tour systems has a positive impact on PE.

H1b: Immersion in 720° virtual tour systems has a positive impact on EE.

H2a: Interaction in 720° virtual tour systems has a positive impact on PE.

H2b: Interaction in 720° virtual tour systems has a positive impact on EE.

Performance Expectancy. PE reflects the usefulness, task completion efficiency, or the achievement of performance perceived by users. It is the most powerful predictor of users' behavioral intention (Venkatesh et al. 2003). In this study, the PE indicates that the use of 720° virtual tour systems meets their expectations of online museum experiences. For example, the system helps users obtain cultural and historical knowledge more efficiently during online museum visits. Therefore, we propose that

H3: PE has a positive impact on the BI to use 720° virtual tour systems.

Personal Innovativeness. PI is defined as an individual's willingness to accept any innovative technology and take the time to try it (Agarwal and Prasad 1998). It was shown to have a significant positive impact on perceived usefulness and perceived ease of use (Kim and Forsythe 2010; Lee et al. 2006; tom Dieck and Jung 2018). Previous work has also highlighted that personal innovativeness directly affects users' intention to use innovative information technologies (Fagan et al. 2012; Yi et al. 2006). Similarly, 720° virtual tour systems share novel characteristics of VR. We propose that

H4a: PI has a positive impact on the PE of 720° virtual tour systems.

H4b: PI has a positive impact on the EE of 720° virtual tour systems.

H4c: PI has a positive impact on the BI to use 720° virtual tour systems.

Effort Expectancy. EE is defined as the user's perception of the difficulty of using the system (Venkatesh et al. 2003). Prior research has shown that this factor strongly influences users' intention to use a technology (Matli and Ngoepe 2021; Rezaei and Ghofranfarid 2018; Venkatesh et al. 2003). Therefore, EE is considered the main predictor in the model, and we hypothesize that

H5: EE has a positive impact on the BI to use 720° virtual tour systems.

Social Influence. SI refers to the extent to which someone believes and adopts the opinions of others. Previous research has shown that social influence is a significant influencing factor of behavioral intention (Monteiro et al. 2022; Venkatesh et al. 2003). Thus, we propose that

H6: SI has a positive impact on the BI to use 720° virtual tour systems.

Facilitating Conditions. FC reflects the effect of users' knowledge and resources on their willingness to use a technology (Venkatesh et al. 2003). In previous studies, FC was considered to have a direct effect on users' intention to use, as well as the use behavior (Venkatesh et al. 2012). For 720° virtual tour systems, users may opt out of using the system if they feel a lack of guidance and instructions. Therefore, we hypothesize that

H7a: FC have a positive impact on the BI to use 720° virtual tour systems.

H7b: FC have a positive impact on the use behavior of 720° virtual tour systems.

Behavioral Intention. BI refers to a person's long-term plan and decision to adopt a technology. It is the key construct that has been adopted by most technology acceptance models (Venkatesh et al. 2003). Venkatesh et al. (2012) demonstrated that BI has a positive impact on use behavior. Thus, we propose that

H8: BI to use 720° virtual tour systems has a positive impact on the use behavior.

6.3.3 Data Collection and Analysis

An online survey study was conducted to collect users' responses to the identified constructs. The survey includes three parts: basic information about participant demographics, questionnaire items about the proposed constructs, and open-ended questions for comments and suggestions. Participants were asked to explore three 720° virtual tour systems for online museum experiences that are publicly available, including the *Palace Museum*,[3] *Suzhou Museum*,[4] and *ShaanXi History Museum*[5] (see Fig. 6.2). We selected them because they are national first-grade museums in China and thus have good quality control of the system usability and content. In addition, the three systems show a good coverage of online museum experiences about historical sites, indoor museum spaces, and archaeological sites. Figure 6.3 shows some example interactions supported in the 720° virtual tour systems.

The survey was distributed on Chinese social media using convenience and snowball sampling methods. The study followed the following procedure. First, we invited participants to read the information sheet and provide their consent. Following this, participants were asked to click on the links of the three 720° virtual tour systems and explore the online exhibitions. In order to obtain reliable evaluations, participants were required to confirm that they had completed the virtual tours before filling out the questionnaire. The questionnaire includes four questions about demographic information, including age, gender, device used, and technology familiarity. Participants were invited to evaluate their experiences and provide ratings for the measurement items, as shown in Table 6.1. They were instructed to rate on a Likert scale from 1

[3] https://pano.dpm.org.cn/.

[4] https://www.szmuseum.com/0pano/new/pano/index.html.

[5] http://hxmbh.sxhm.com:6868/pano/vrshow/showhxm.html?t=20210209142453245358.

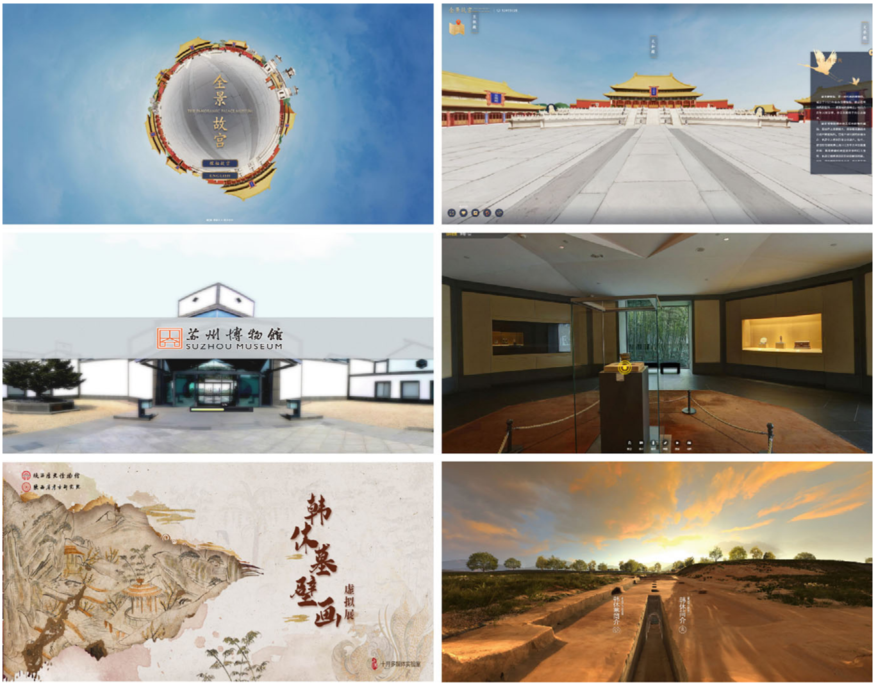

Fig. 6.2 Screenshots of three 720° virtual tour systems for online museum experiences: The Palace Museum (top), Suzhou Museum (middle), and Shaanxi History Museum (bottom)

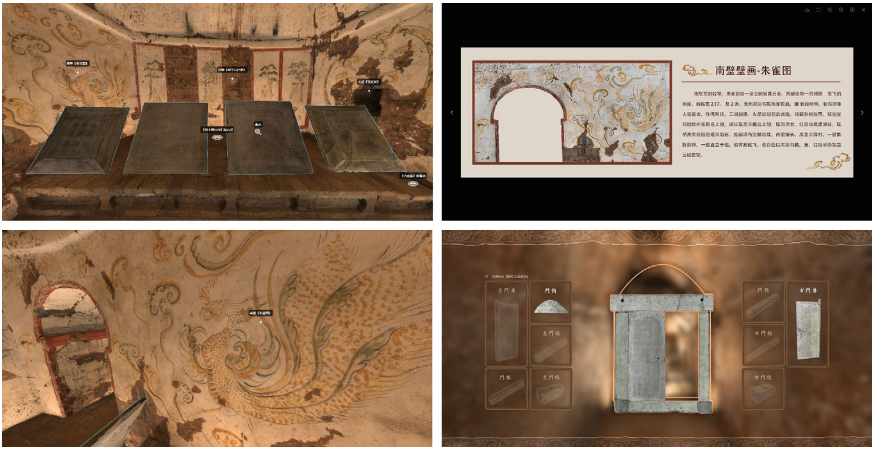

Fig. 6.3 Example interactions supported in the online museum experiences, including interactive labels, image and text descriptions, a close-up view of the mural, and a puzzle game

Table 6.1 Measurement items of the constructs and the factor loadings

Construct	Item	Description	Loading
IM	IM1	To what extent do you feel about the immersion of this system?	1.000
IN	IN1	To what extent do you feel about the interaction of this system?	1.000
PE	PE1	Using this system enables me to accomplish tasks more quickly	0.957
	PE2	Using this system can meet my requirements more effectively	0.976
	PE3	Using this system can meet my needs for obtaining information	0.944
PI	PI1	Compared with the people around me, I have a higher degree of innovativeness.	0.982
	PI2	I am willing to spend time and energy learning innovative technologies	0.978
EE	EE1	My interaction with this system would be clear and understandable	0.928
	EE2	It would be easy for me to become skillful at using this system	0.937
	EE3	Learning to operate this system is easy for me	0.918

(continued)

(strongly disagree) to 5 (strongly agree), and ‘this system’ in the statements refers to the 720° virtual tour systems. The final part of the questionnaire includes open-ended questions eliciting participants’ comments about system limitations and suggestions for improvements. This study has been approve by the University Ethics Committee of Xi’an Jiaotong-Liverpool University.

Table 6.1 (continued)

Construct	Item	Description	Loading
SI	SI1	I care if people who are important to me think that I should use this system	0.956
	SI2	The publicity of the system in my surroundings will encourage me to try to use this system	0.962
FC	FC1	I have control over using this system	0.974
	FC2	I have the resources and knowledge necessary to use this system	0.952
	FC3	If I get guidance and instructions, I will use this system	0.917
BI	BI1	I am willing to use this system	0.846
	BI2	I intend to use this system in the next few months	0.838
	BI3	I am willing to recommend this system to people around me	0.818
UB	UB1	I am using this system	0.818
	UB2	I recommended my friend to use this system	0.821
	UB3	I will continue to use this system in the future	0.820

The survey data was analyzed using IBM SPSS Statistics and SmartPLS. We performed descriptive statistics on the demographics data and conducted structural equation model analysis to verify the research model and the proposed hypotheses.

6.4 Results

6.4.1 Participant Demographics

In total, we received 150 valid responses (85 females and 65 males). Participants aged between 18 and 35 (M = 23.19, SD = 2.68). More than half of the participants (55.33%) used PC when experiencing the 720° virtual tour systems, followed by smartphones (34.67%) and tablets (9.33%). On a 5-point Likert scale (5 = Very familiar), participants were familiar with the technology (M = 3.81, SD = 0.93). Overall, participants reported a high degree of interaction (M = 3.95, SD = 0.96) and immersion (M = 3.96, SD = 0.91) when using the 720° virtual tour systems.

6.4.2 Measurement Reliability and Validity

We analyzed the reliability and validity to examine the robustness of the measurement model. Specifically, we examined the Cronbach's alpha (CA) and composite reliability (CR) values for all constructs to test the internal reliability. For the convergent validity of the research models, we calculated the average variance extracted (AVE) of each construct for assessment. The results are shown in Table 6.2.

Comparing our results to the suggested thresholds (Fornell and Larcker 1981), the CA values for all constructs were above the standard value of 0.7 and ranged from 0.756 to 1.000, showing a high measurement reliability. The CR values were above the standard value of 0.7 and ranged from 0.757 to 1.000, which means that the constructs have high internal consistency. Overall, the measurement model shows a good reliability.

Table 6.2 Measurement validity and reliability results, showing the Cronbach's Alpha (CA), Composite Reliability (CR), and Average Variance Extracted (AVE)

Construct	CA	CR	AVE
Immersion	1.000	1.000	1.000
Interaction	1.000	1.000	1.000
Performance expectancy	0.956	0.957	0.919
Personal innovativeness	0.959	0.966	0.961
Effort expectancy	0.919	0.922	0.861
Social influence	0.912	0.916	0.919
Facilitating conditions	0.943	0.946	0.898
Behavioral intention	0.781	0.782	0.696
Use behavior	0.756	0.757	0.672

Table 6.3 Analysis results of discriminant validity

	EE	FC	IM	IN	PE	PI	SI
EE	**0.928**						
FC	0.925	**0.948**					
IM	0.872	0.880	**1.000**				
IN	0.851	0.787	0.682	**1.000**			
PE	0.923	0.947	0.892	0.733	**0.959**		
PI	0.811	0.918	0.892	0.681	0.893	**0.980**	
SI	0.865	0.923	0.899	0.752	0.896	0.942	**0.959**

In addition, the factor loadings of all measurement items were greater than the critical value of 0.7, ranging from 0.818 to 1.000 (see Table 6.1). The AVE values of all constructs were greater than the critical value of 0.5, ranging from 0.672 to 1.000. This indicates a high level of convergent validity of the measurement model.

For discriminant validity (Fornell and Larcker 1981), we examined the square root of AVE of each construct to check if it is greater than its correlation with other constructs (see Table 6.3). The results showed that all values on the diagonal were greater than the values in the same column and row; namely, the square root of AVE of the latent variables was greater than the correlation coefficient with all variables. Therefore, the measurement model shows acceptable discriminant validity.

6.4.3 Structural Equation Modeling Analysis and Hypotheses Testing

We adopted partial least squares (PLS) regression and bootstrap resampling method to conduct the structural equation modeling analysis. To evaluate the overall quality of the research model, we analyzed the coefficient of determination (R^2) to test the predictive power of the model and the predictive relevance (Q^2) to establish the predictive relevance of the endogenous constructs.

Coefficient of determination (R^2). The results showed that the R^2 of PE, EE, BI, and UB were 0.858, 0.883, 0.973, and 0.587, respectively, implying that the structural model has substantial ($R^2 > 0.75$) predictive power for PE, EE, and BI, and moderate ($R^2 > 0.5$) predictive power for UB (Hair et al. 2011).

Predicting relevance (Q^2). We also checked the value of Q^2 to examine the predicting relevance (Geisser 1974; Stone 1974). The results showed that the Q^2 of BI and UB were 0.663 and 0.381, respectively. Both values are greater than zero (Leguina 2015), indicating that the structural model has acceptable predictive relevance.

Hypotheses testing. Table 6.4 and Fig. 6.4 include the detailed statistics of the path coefficients and the hypotheses testing results. With the confirmation of significance

Table 6.4 Path coefficients (β) and hypotheses testing results

Hypothetical path	β	SD	t statistics	p value	Result
H1a: IM → PE	0.406	0.057	7.102	**0.000**	Supported
H1b: IM → EE	0.550	0.060	9.220	**0.000**	Supported
H2a: IN → PE	0.177	0.041	4.261	**0.000**	Supported
H2b: IN → EE	0.480	0.036	13.471	**0.000**	Supported
H3: PE → BI	0.278	0.042	6.555	**0.000**	Supported
H4a: PI → PE	0.411	0.066	6.234	**0.000**	Supported
H4b: PI → EE	−0.006	0.060	0.104	0.917	Not supported
H4c: PI → BI	−0.004	0.047	0.089	0.929	Not supported
H5: EE → BI	0.235	0.039	6.056	**0.000**	Supported
H6: SI → BI	0.138	0.051	2.715	**0.007**	Supported
H7a: FC → BI	0.369	0.048	7.624	**0.000**	Supported
H7b: FC → UB	0.080	0.232	0.346	0.729	Not supported
H8: BI → UB	0.688	0.224	3.069	**0.002**	Supported

of H1a ($\beta = 0.406$, $p<0.001$), H1b ($\beta = 0.550$, $p < 0.001$), H2a ($\beta = 0.177$, $p < 0.001$), and H2b ($\beta = 0.480$, $p<0.001$), it can be inferred that both immersion and interaction have significant positive effects on performance expectancy and effort expectancy. In addition, since H4a ($\beta = 0.411$, $p<0.001$) is supported and H4b ($\beta = -0.006$, n.s.) is rejected according to the results, personal innovativeness only has a significant positive impact on performance expectancy. The proposed H3 ($\beta = 0.278$, $p<0.001$), H5 (β=0.235, $p < 0.001$), H6 ($\beta = 0.138$, $p < 0.01$), and H7a ($\beta = 0.369$, $p<0.001$) were confirmed. Performance expectancy, effort expectancy, social influence, and facilitating conditions have a significant positive impact on behavioral intention. Besides, H8 is also supported ($\beta = 0.688$, $p < 0.01$), confirming that behavioral intention has a significant positive impact on use behavior.

6.5 Discussion

Our investigation of the technology acceptance of 720° virtual tour systems showed that users' behavioral intention is positively influenced by performance expectancy, effort expectancy, social influence, and facilitating conditions. Users' behavioral intention positively influences their use behavior. These are consistent with the UTAUT model. One exception was that facilitating conditions did not show a significant influence on use behavior of 720° virtual tour systems. This indicates that

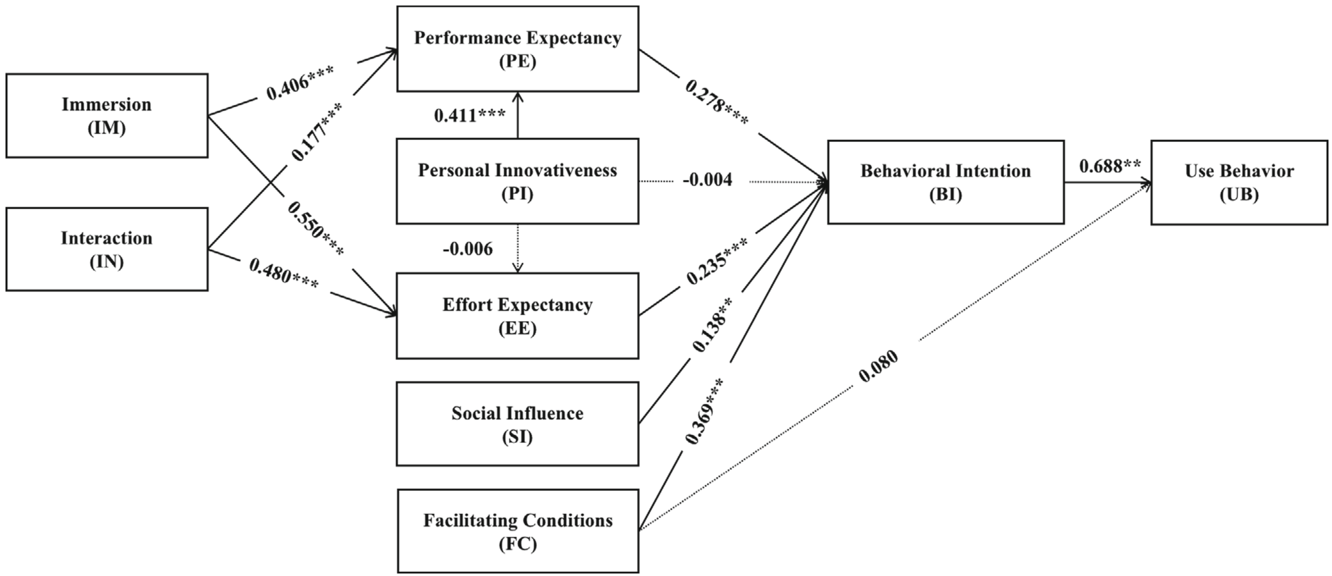

Fig. 6.4 Model validation results. Values on the path are coefficients (β). *p<0.05; **p<0.01; ***p<0.001. A dashed line indicates an insignificant path

while having facilitating conditions contributes to users' intention to use the system, it is insignificant when users are actually using it.

Based on UTAUT, we introduced three constructs related to technology and user characteristics in our research model, namely immersion, interaction, and personal innovativeness. Our results showed that immersion and interaction have positive impacts on performance expectancy and effort expectancy. Personal innovativeness has a positive impact on performance expectancy but shows no direct influence on effort expectancy or behavioral intention. Here, we discuss our findings in detail.

6.5.1 Immersion and Interaction in 720° Virtual Tour Systems

We examined the technology characteristics of 720° virtual tour systems, namely immersion and interaction, and found them to be significant antecedents of performance expectancy and effort expectancy. The positive effects of immersion indicate that the sense of being there in the virtual space facilitates users' expectations of their performance and effort. The higher the degree of immersion perceived by users, the more likely that users will find the system useful and easy to use. Immersion is arguably the greatest technology characteristic of 720° virtual tour systems. Thus, immersive experiences should be prioritized to increase users' intention to use the technology. Suggestions such as to '*improve the image clarity*' and '*avoid the lagging between the transitions*' were provided by participants for improving immersion.

Our results on the effect of interaction slightly differ from the findings in (Barrett et al. 2023). In their study, they found a significant effect of interaction on effort expectancy but not performance expectancy. In addition, the effect of effort expectancy on the intention to use was not significant. The authors discussed that their participants encountered some difficulties when interacting with the VR system. However, in our case, participants found the 720° virtual tour systems easy to use, and the impact of interaction on behavioral intention mediated by effort expectancy was found significant. When examining the suggestions left by participants in the open-ended questions, we found that they expected the system to be more interactive. For example, a participant commented that '*the interactive experience needs improvement*', and they hope to '*add more interactions to make the system more interesting*'. These have pointed to the need for rich interactive features to engage users in the future design of 720° virtual tour systems.

6.5.2 Personal Innovativeness in the Adoption of Novel Technologies

As a new construct introduced in our model, personal innovativeness was found to have a significant positive influence on performance expectancy. Users with a high degree of personal innovativeness are more likely to find the 720° virtual tour systems useful in obtaining cultural and historical knowledge. This will contribute to their intention to use it for online museum visits. While previous work showed a direct influence of personal innovativeness on behavioral intention (Fagan et al. 2012; Yi et al. 2006), our study showed that this effect is fully mediated by performance expectancy.

Our survey sample included a large number of responses from age groups that are relatively young. Previous work showed that teenagers and young adults are user groups who are willing to try out new things and learn new technologies (Xu et al. 2023a). Our participants reported that they found the system '*very easy to use*' and '*much cooler than the real museum*'. For cultural institutions that attempt to adopt 720° virtual tour systems for online museum experiences, it would be reasonable to target these user groups who are naturally keen to use novel technologies. This is in line with observations and findings in previous research on innovative technology use.

6.5.3 Implications for System Design and Development

Based on the above analysis and results, we suggest the following design guidelines for the design and development of 720° virtual tour systems in the future.

First, ensure image clarity and smooth transitions between 720° panoramic views. Our results showed that immersion has a strong effect on both performance expectancy and effort expectancy; thus, it should be prioritized for 720° virtual tour systems. Participants' responses in the questionnaire showed that immersion is closely related to the image quality and users' control over movements in the virtual environment, such as the smoothness in transitions between panoramas. These inform the design to improve users' immersion of the 720° virtual tour systems. This will contribute to users' performance expectancy and effort expectancy, and improve their intention to use the technology.

Second, design for interactive and playful narratives. Participants reported that they enjoyed the interactive experience in the online experience of Shaanxi History Museum: '*I like that I can play interactive games in the scene*'. The system (see Fig. 6.3) provided detailed information by placing interactive icons on top of the panoramic view. It also adopted some playful settings, such as letting users reassemble a stone gate from ruins through a puzzle game. These interactions have received positive feedback from participants. Designing such interactions with rich cultural knowledge and engaging gameplay will contribute to users' performance expectancy, effort expectancy, and intention to use the system.

Third, provide a comprehensive introduction to the historical and cultural background during the tour and make use of multimedia where appropriate. From the questionnaire results, we found that participants were concerned about gaining historical and cultural knowledge after using the 720° virtual tour systems. For example, several participants commented that they expected to have more detailed descriptions about the architecture, and suggested providing complementary images and texts, and audio guide systems. Therefore, future online museum experiences should provide users with a rich array of media to convey knowledge information that is comprehensive and understandable, to improve their performance expectancy and promote their behavioral intention to use this system.

Fourth, optimize the use for different user groups and provide necessary instructions. While most participants found the system easy to use, one participant pointed out the need to '*add some tutorial functions to help the elderly learn how to use the system*'. Similarly, another comment also highlighted the elderly user group: '*I hope to promote the system so that more people can use it, especially the elderly who cannot travel can use this system to feel that they are traveling*'. Given that effort expectancy has a significant positive impact on behavioral intention, designers should try to make the system easy to access and operate, catering to the needs of different user groups, similar to other applications like games (Xu et al. 2021). Although good designs are often easy to learn and intuitive, beginner guides and supporting instructions can be helpful to the adoption of novel technologies. This also addresses the positive influence of facilitating conditions on behavioral intention.

6.5.4 Limitations and Future Work

This research has some limitations. Although we collected a reasonable sample size, it showed a limited coverage of age groups. Most respondents are young adults aged between 18 and 35. Although the elderly were identified as a potential user group of 720° virtual tour systems, our sample did not include this age group. Future studies should attempt to reach a wider range of user groups. Second, our survey study was conducted online. As a result, it was difficult to strictly control the time users spent on the three 720° virtual tour systems. The differences in the amount of time they spent and the digital content they viewed and interacted with may have influenced their responses. Third, our current research did not consider all factors that may affect the use of 720° virtual tour systems for online museum experiences. We mainly explored factors related to the novel characteristics of the technology. Future work may explore factors that are specific to the museum learning context, such as interest, perceived enjoyment, and learning motivation. In addition, the three systems we selected were possibly created using different hardware, and our participants were using three different devices (PCs, smartphones, and tablets) with varying display sizes and resolutions. While this demonstrates broad device coverage for 720° virtual tour systems, the variance in the platform could elicit different experiences (Lu et al. 2023) and remains a limitation of our data. Finally, the effect of using 720° virtual tour systems should be more systematically evaluated by incorporating a control group, such as individuals participating in actual museum visits. Nevertheless, our study contributes to a deeper understanding of the effects of immersion, interaction, and personal innovativeness on the user acceptance of 720° virtual tour systems, providing insights into the design of future online museum experiences.

6.6 Conclusion

Providing high visual fidelity of museum exhibits with accessibility from standard devices, web-based 720° virtual tour systems have gained significant popularity in the past few years. They facilitate the online display of museum exhibitions and historical sites in high resolution, showcasing significant potential for delivering digitized museum experiences to a wide audience. This research validates a model extended from the Unified Theory of Acceptance and Use of Technology (UTAUT) to understand user acceptance of 720° virtual tour systems for online museum experiences. We introduced two constructs related to technology characteristics (immersion and interaction) and one construct about user characteristics (personal innovativeness). Through the data analysis of 150 online survey responses, we found that (1) immersion and interaction positively influence performance expectancy and effort expectancy; and (2) personal innovativeness has a positive impact on users' performance expectancy, but not effort expectancy or behavioral intention. The positive impacts of performance expectancy, effort expectation, social influence, and facilitating conditions on behavioral intention have also been confirmed. Overall, the proposed model demonstrates substantial predictive power for users' behavioral intention to use 720° virtual tour systems ($R^2 = 0.976$). Based on the findings and participants' suggestions, we suggest design guidelines focusing on the support for immersion and interaction in 720° virtual tour systems, the presentation of knowledge and information for online museum experiences, and the need for facilitating conditions to improve the ease of use for various user groups. Our work contributes to a deeper understanding of user acceptance of 720° virtual tour systems and reveals the significant effects of immersion, interaction, and personal innovativeness on its use for online museum experiences.

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