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Immersive Cultural Heritage: Exploring Users' Attitudes and Behavioral Intentions Towards the Dunhuang Digital Museum

Yutong Chen[1] & Xinyi Chen[1]

[1] School of Art, Northeast Electric Power University, Jilin 132000, China

Correspondence: Yutong Chen, School of Art, Northeast Electric Power University, Jilin 132000, China. E-mail: 1417812624@qq.com

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Abstract

The advent of augmented reality, virtual reality and artificial intelligence technologies and its innovative applications has revolutionized the museum landscape, ushering in a new era that sharply diverges from the past. Although digital museums have attracted the attention of scholars, the relevant research is still insufficient. The study formulates a comprehensive theoretical model based on technology acceptance model, presenting 13 hypotheses that impact users' sustained intent towards digital museums. Using SPSS 26.0 software, this study employed structural equation modeling to analyze the data collected from 382 visitors of the Dunhuang Digital Museum and validate the hypotheses. Results showed that relative advantage, self-efficacy and media richness influence users' attitudes and thus behavioral intentions through perceived ease of use; relative advantage and technostress influence users' attitudes and thus behavioral intentions through perceived usefulness; social mimetism and digital experience not only influence behavioral intentions by influencing attitudes, but also have a direct impact on behavioral intentions. The findings contribute to the enrichment of academic theories and offer professionals a valuable reference for enhancing user experience services in digital museums.

Keywords: Digital museum; Dunhuang; Virtual exhibition hall; Technology acceptance model; Attitudes; Behavioral intention

1. Introduction

The progression of augmented reality (AR), virtual reality (VR) and artificial intelligence (AI) technologies has spurred the rapid digital evolution of museum intelligence (Fuentes-Moraleda et al., 2021; Zollo et al., 2021; Hammady et al., 2020; Shi et al., 2023). Cultural relics exhibited in traditional museums are confined to viewing through display windows, lacking interactive engagement for viewers (Ray, 2017; Kenderdine, 2013). For instance, at the Dunhuang caves in China, measures are implemented to prevent the damage to cultural relics. These include restrictions on the frequency of openings and visiting times, and the prohibition of lighting within the caves. Consequently, tourists experience significantly diminished viewing encounters, and the information available to them is severely limited, hindering a comprehensive understanding of the profound cultural significance of Dunhuang caves. In contrast, digital displays have the capability to capture the entirety, specific sections, and intricate details of the original artifacts, facilitating a more thorough interpretation of the Dunhuang caves (Wu et al., 2022; Deng et al., 2023).

The rise of digital museums has prompted a shift from the traditional "object-centric" operational logic to an "experience-centric" paradigm, playing a pivotal role in advancing the digitization of social service resources (Meng et al., 2023; Hein, 2000). Digital museums harness computer networks to seamlessly integrate and consolidate a diverse range of cultural relics resources. By incorporating mobile terminals with virtual technology, these museums present cultural relics in a more comprehensive, vivid, and realistic manner, thereby facilitating the sharing of resources. This not only expedites the integration of the cultural and museological industry into the digital information age but also achieves the modernization of cultural relic display and protection (Hammady et al., 2020; Wu et al., 2022).

The Dunhuang Museum, a significant component of the global cultural heritage, underscores the noteworthy contributions of Chinese civilization. Its exhibitions focusing on the art of the Mogao Caves and the ancient Silk Road offer invaluable historical evidence of world civilization (Song, 2023). On April 18, 2023, International Monuments and Sites Day marked the official launch of the world's first overtime participatory museum, guided

by China's State Administration of Cultural Heritage and collaboratively developed by the Dunhuang Research Academy and Tencent. It is anticipated that by year-end, the internationalized products of the Dunhuang Digital Museum (DDM) will be introduced in the European region, fostering the exchange of knowledge on international cultural heritage.

Understanding how visitors integrate digital resources into their daily lives is essential for appropriately recognizing cultural heritage, and this comprehension is pivotal for the success of digital museums in the information age. Despite the proliferation of digital museum scholarship, a noticeable gap exists in the academic research on the DDM, particularly in the realm of user attitudes and behavioral intentions. Much of the current literature remains confined to qualitative research, primarily delving into the conceptual exploration of digital museums and the analysis of narrative models (Tong, 2020; Zhang, 2011). Unfortunately, there is a dearth of empirical evidence assessing the willingness to engage with digital museums from the standpoint of user behavior. Our study aims to address this theoretical gap by constructing a comprehensive research framework based on the Technology Acceptance Model (TAM) to delve into user acceptance and willingness to use the DDM. We expanded upon previous studies by incorporating evaluation dimensions such as self-efficacy, technostress, media richness, social mimetism, and digital experience. Employing a survey methodology, we analyzed the results through structural equation modeling. These findings carry both theoretical and practical implications, contributing to the enrichment of academic theories and assisting professionals in optimizing user experience services within digital museums.

2. Literature Review and Theoretical Framework

2.1 Dunhuang Culture

The Dunhuang Museum serves as the administrative institution for the UNESCO World Heritage site, the Mogao Caves in Dunhuang, and is also classified as a first-tier museum in China. Established in 1944, it is located in Dunhuang City, Gansu Province. The museum is responsible for the protection, research, exhibition, and inheritance of the Mogao Caves and other world cultural heritage sites. It serves as the National Research Center for the Protection of Ancient Murals and Earthen Sites and is a key research base for the protection of ancient murals recognized by the State Administration of Cultural Heritage. The museum currently possesses over 2000 mural replicas, more than 50 colored sculptures, and reproductions of 11 original large caves. It has been inscribed on the UNESCO World Heritage List and has held over 20 Dunhuang art exhibitions domestically and internationally from 1943 to the end of 2000, earning recognition both at home and abroad.

Several scholars have begun to pay attention to Dunhuang culture and have conducted valuable research. For instance, Song (2023) explored translation issues in Dunhuang culture from a cultural translation perspective. Zeng et al. (2022) proposed a novel mobile visual search model for Dunhuang murals, establishing a mobile visual search service system for the protection of Dunhuang cultural heritage, facilitating user access to knowledge. Additionally, literature on Dunhuang focuses on disciplines such as geography (Li et al., 2016), religious studies (Liu, 2020), and computer technology (Zhou et al., 2022).

Dunhuang's rich cultural resources make Dunhuang a thriving tourist city. However, the Mogao Caves in Dunhuang are not conducive to large numbers of visitors due to the emission of carbon dioxide and moisture in the limited space, accelerating the oxidation and peeling of the murals (Demas et al., 2015). Therefore, in the 1990s, the Dunhuang Museum pioneered digital exploration and practice, resulting in a rich collection of digital cultural relics. These digital resources include high-fidelity digital images of cultural relics, three-dimensional reconstruction digital resources, virtual roaming digital resources, and audio-visual creative works of cultural relics. By integrating physical museums with online platforms for digital cultural relic displays, the dissemination and development of Dunhuang culture have been greatly facilitated, further advancing international cultural exchanges (Agnew et al., 2012).

2.2 Digital Museum

Various definitions have been employed by scholars to characterize digital museums (Li et al., 2012; Kim, 2018). From a technical support perspective (Cunliffe et al., 2001; Dong et al., 2006; Skov & Ingwersen, 2014), digital technologies are employed to reshape the original physical collection model, transforming museums into online data resources and enhancing the dissemination of valuable information through the web. Notably, the scope of digital museums in this paper is confined to those utilizing the web for presentation and dissemination. This transformation converts physical collections into data resources, utilizing mobile devices to access content and collections both on-site and off-site, transcending the constraints of time and place, providing audiences with an entirely new way to experience museums (Galani & Kidd, 2019).

The primary characteristics of digital museums are delineated by Hung et al. (2016) and Wu et al. (2022): The digital museum preserves the essential functions of the physical museum, offering a user-friendly interface. It integrates exhibits and relevant information displays akin to traditional museums while also incorporating effortless search functions and navigation systems. Digital museums facilitate access to collections through digital technology and mobile devices, unrestricted by physical location and time constraints. These access methods surpass the limitations of physical space and time, affording greater flexibility. Digital museums engage users in non-linear viewing and experiences while endeavoring to enhance the relevance and accessibility of collections through digital technologies such as personalized search (Dong et al., 2006), multi-touch screens, interactive 3D, and augmented reality. These technologies enable visitors to cultivate a deeper sense of belonging, connection, and experience (Light et al., 2018).

Currently, there is only one retrievable study on the DDM, which focuses on its presence on the WeChat Mini Program. Specifically, it examines the image and shaping process of the Digital Dunhuang from the perspective of religious tourism (Song, 2023). However, this literature employs the walkthrough method and lacks more specific quantitative analysis. Therefore, our study, to the best of our knowledge, may be the first to adopt a quantitative research approach from the perspective of user experience to investigate the DDM. Specifically, we explore users' attitudes and behavioral intentions towards the DDM, thus making a significant contribution to the development of relevant literature.

2.3 User Experience

The term 'user experience' denotes the cognitive perceptions and reactions individuals harbor towards the products, systems, or services they utilize or expect to use. The advancements in information and communication technology, along with related innovations, have precipitated a significant transformation in the nature of museums, shifting the focus from object-oriented to experience-oriented (Hein, 2000), with digital museums gaining particular prominence. These institutions are committed to augmenting the significance and accessibility of their collections, rendering them more captivating to visitors and fostering a heightened sense of rapport and experience (Light et al., 2018).

Similarly, Lee and Kim (2017) posit that in information interaction, both technical elements, such as usability and ease of system use, and non-technical elements, such as the quality of enjoyment and visual appeal, impact the user experience of a website. Various forms of digital media serve as drivers for enhancing the user experience. Consequently, multiple researchers have explored digital technologies and their effects on visitor experiences, proposing a user-focused strategy to bolster the evolution of digital museum advancements (Skov & Ingwersen, 2014; Walsh et al., 2020).

However, further refinement is necessary, particularly in considering how digitization can enhance the overall visitor experience based on individual needs and selecting the most suitable solution for this purpose. This has emerged as a significant focus for professionals in the field. Table 1 offers an overview of prior investigations into users' behavior and experience in digital museums. The aforementioned studies scrutinized users' perceptions of digital museums and provided justifications for their initial and subsequent utilization of digital museums. The inclinations and attitudes of audiences toward the use of digital museums are pivotal for enhancing museum experiences and advancing cultural promotion.

Table 1. Definitions of theoretical constructs

Construct	Operational definition	Source
Perceived Usefulness (PU)	The extent to which users think they would benefit from a digital museum	Davis et al. (1989); Taylor & Todd (1995); Bhattacherjee (2001)
Perceived Ease-of-Use (PEOU)	The degree to which users find digital museums easy to use, learn, and understand.	Davis et al. (1989); Taylor & Todd (1995); Hung et al. (2016)
Attitude (ATT)	Positive or negative attitudes of users when using the digital museum.	Davis et al. (1989); Taylor & Todd (1995); Hung et al. (2016); Khalil et al. (2023)
Behavior Intention (BI)	The behavioral intention of the user to continue using the digital museum.	Davis et al. (1989); Taylor & Todd (1995); Wu et al. (2022)
Technostress (TECH)	The pressure caused by the process of users using digital museums to acquire knowledge.	Kuo et al. (2009); Chen et al. (2019)
Relative advantage (RA)	Digital museums are more convenient and interesting than traditional physical	Rogers (2005); Agarwal & Prasad (1998)

Construct	Operational definition	Source
	museums.	
Media Richness (MR)	Digital museums provide timely feedback, multiple social cues, and personalization and linguistic diversity to present artifacts and historical stories.	Daft & Lengel (1983); Lee et al. (2007); Hung et al. (2016)
Social mimetism (SM)	Users use digital museums to avoid missing out on "fitting in" opportunities (FOMO).	Abel et al. (2016); Alutaybi et al. (2020)
Self-efficacy (SE)	Users' confidence in their ability to use digital museums.	Venkatesh & Davis (2000); Venkatesh et al. (2003); Venkatesh & Bala (2008); Shephard & Pookulangara (2020)
Digital experiences (DE)	The digital experience of users using the digital museum (sensory experience, emotional experience, behavioral experience...).	Brakus et al. (2009); and Zollo et al. (2021)

Technology Acceptance Model (TAM)

Founded on the theory of rational behavior, Davis (1989) developed the TAM, wherein he streamlined the factors influencing attitudes into perceived usefulness and perceived ease of use, excluding subjective norms. TAM primarily aims to provide a research model for explaining the adoption of information technology (Letchumanan & Tarmizi, 2011; Nguyen et al., 2022). It underscores user acceptance by elucidating the associations among perceived usefulness, perceived ease of use, attitudes toward use, and behavioral intention as determinants of information technology (Chen et al., 2018). Specifically, when users perceive information technology as useful and easy to use, they are more inclined to cultivate positive attitudes and intentions to persist in its use (Davis et al., 1989).

Davis (1992) integrated various exogenous variables affecting perceived use and perceived ease of use into the TAM model, while Venkatesh and Bala (2008) introduced cognitive and other factors (feelings of anxiety) to the TAM for better explanation. As a result, some scholars have noted that navigability, self-efficacy, and experience of use influence perceived ease of use and perceived usefulness in studies concerning digital collections (Shephard & Pookulangara, 2020). Despite many studies adopting TAM as their research model, they do not adequately reflect the nature of user behavior. To underscore the importance of intrinsic motivation for using the digital museum, several exogenous variables were incorporated for in-depth assessment.

3. Research Hypotheses

3.1 Perceived Usefulness (PU) and Perceived Ease of Use (PEOU)

Davis (1989) defined perceived usefulness (PU) as the extent to which an individual believes that the use of a new technology enhances job performance. In numerous studies on the adoption of information technology, researchers have posited that perceived usefulness is a pivotal factor influencing the adoption and sustained utilization of information systems, such as Facebook (Lee et al., 2012), and mobile devices (Morosan and DeFranco, 2014). These inquiries suggest that enhancing perceived usefulness can aid users in fostering more positive attitudes towards using a particular technology or service, consequently leading to increased actual usage. Based on this, it is reasonable to assume that if users perceive the DDM as an effective means of acquiring knowledge, they are more likely to regard it as useful and cultivate a more positive attitude towards the use of digital museums.

Perceived ease of use (PEOU) refers to a person's perception of how easy or difficult it is to use a specific technological system when using it. The term has been further elucidated by other researchers to encompass the effort required to use the system (Rogers, 1995; Venkatesh & Davis, 2000). The findings of many previous studies have substantiated a positive correlation between individuals' perceived ease of use and their attitudes toward the use of technology (Hung et al., 2016). Therefore, it is reasonable to predict in this study that if users perceive they can easily access the required content via the DDM, they are more likely to perceive it as user-friendly. Consequently, they will develop a more positive attitude towards using the digital museum. Hence, we assert the following hypothesis.

H1: Perceived usefulness (PU) has a positive effect on users' attitudes (ATT).

H2: Perceived ease of use (PEOU) has a positive effect on users' attitude (ATT).

3.2 Attitude (ATT) and Behavior Intention (BI)

In the TAM, the endogenous factors, such as attitude and behavioral intention, play a pivotal role. Attitude, in this context, refers to the personal development of favorable or unfavorable feelings towards the adoption of technology, influencing the intention to use the technology and the decision to sustain its use. Scholars posit that attitudes toward the use of digital museums are shaped by social mimetism, perceived ease of use, and perceived usefulness, as evidenced in research on attitude (ATT) (Hung et al., 2016; Khalil et al., 2023). Behavioral intention (BI), representing a user's willingness to use and sustain the use of technology, emerges as a crucial determinant of technology adoption (Wu et al., 2021; Ma et al., 2023). Hung et al. (2016) observed that a user's attitude toward a museum employing an Internet-based platform for displays strongly predicts their intention to revisit that digital museum. Numerous previous studies have consistently demonstrated a positive correlation between users' attitudes toward technology and their behavioral intentions. Consequently, it is reasonable to hypothesize that users with positive attitudes toward the DDM are more inclined to continue using it. Thus, we propose the following hypothesis:

H3: Users' attitude toward (ATT) has a positive effect on users' behavior intention (BI).

3.3 Relative Advantage (RA)

Relative Advantage is defined as the extent to which a new technological innovation surpasses a traditional one in superiority, yielding more benefits than its predecessor (Rogers & Shoemaker, 1983). Individuals exhibit a greater inclination to adopt a new innovation when it is perceived to be more convenient and useful, contributing to improved efficiency and effectiveness (Lin & Chen, 2012). These studies consistently affirm that participants' attitudes and behavioral intentions to utilize digital museums are positively influenced by the perceived relative advantage, grounded in the dimensions of perceived usefulness (PU) and perceived ease of use (PEOU) (Lee, 2007; Lee et al., 2011). Therefore, in this study, we can reasonably predict that users are more likely to perceive the DDM as useful and easy to use if they believe it enhances the efficiency of knowledge acquisition compared to offline alternatives. Consequently, the following hypotheses are proposed:

H4: Relative advantage (RA) has a positive impact on perceived usefulness (PU).

H5: Relative advantage (RA) has a positive impact on perceived ease of use (PEOU).

3.4 Self-efficacy (SE) and Media Richness (MR)

Self-efficacy (SE) refers to a respondent's belief in their ability, knowledge, or skills to perform an activity. It is commonly integrated into TAM frameworks as an evaluative factor influencing perceived ease of use (Venkatesh & Bala, 2008). The examination of self-efficacy and other contributing factors is essential for enhancing the understanding of how these elements impact perceived ease of use (Venkatesh, 2000). Several prior studies have consistently affirmed a positive relationship between individuals' self-efficacy and their perceived ease of use of technology (Song & Wang, 2010). In the context of this research, self-efficacy pertains to users' confidence in navigating the DDM. Thus, it is reasonably foreseeable that users who feel confident in using the DDM are more likely to perceive it as easy to use, thereby influencing their usage attitudes and behavioral intentions. Accordingly, we propose the following hypothesis:

H6: Self-efficacy (SE) has a positive effect on the perceived ease of use (PEOU).

Media richness (MR) refers to the capacity of the information provided by the media to alter the understanding of the recipient within a specific timeframe (Daft & Lengel, 1983). Its assessment criteria encompass immediate feedback, number of cues, channels of use, personalization, and linguistic diversity, with most digital museums incorporating media that fulfill all these criteria. Numerous studies have illustrated that multimedia platforms, facilitating the exchange of diverse and comprehensive information, are more likely to be perceived as valuable and easy to use (Wirtz et al., 2013; Hung et al., 2016). Consequently, in this study, it is reasonable to anticipate that if users perceive the DDM as capable of presenting cultural relics through multiple mediums, including providing timely feedback and multiple cues, they will be more inclined to consider it valuable and easy to use, thereby influencing their utilization of the digital museum. Hence, we propose the following hypothesis:

H7: Media richness (MR) positively influences perceived ease of use (PEOU).

3.5 Social Mimetism (SM)

Social mimetism (SM) is defined as an individual's imitative behavior, often characterized by the fear-of-missing-out (FOMO) (Abel et al., 2016). FOMO is conceptualized as a generalized concern that others may derive beneficial experiences in one's absence (Przybylski et al., 2013). The phenomenon of FOMO has attracted significant attention in the realm of social media usage, particularly on social networking sites. FOMO

encapsulates the apprehension and unease felt by individuals who fear disconnection from enjoyable occurrences and encounters within their broader social circle (Przybylski et al., 2013; Fioravanti et al., 2021). A reasonable hypothesis suggests that, due to social pressure and imitation, participants are more inclined to increase their engagement with the DDM to avoid the fear of missing out on being part of the group. Consequently, two hypotheses are posited.

H8: Social mimetism (SM) has a positive effect on attitudes toward using (ATT).

H9: Social mimetism (SM) has a positive effect on behavioral intention (BI).

3.6 Technostress (TECH) and Digital Experience (DE)

Technostress refers to the psychological and physical stress caused by individuals' inability to adapt to changes in technology and cope with the associated demands (Brod, 1984; Torres et al., 2021). Recent studies have highlighted technological stress as a significant factor affecting the perceived usefulness of technology and the willingness of users to continue using mobile technology (Verkijika, 2019; Khlaif et al., 2022). At elevated levels of technostress, users are more likely to experience discomfort with technology use (Heponiemi et al., 2021) and perceive it as worthless (Swilley, 2010). This suggests that individuals often engage in behaviors to avoid discomfort, particularly actions contributing to heightened psychological stress (Steelman & Soror, 2017). Following our discussion, it is reasonable to predict that users who effectively use the DDM can acquire relevant knowledge, yet they may also face increased skill tasks, leading to more challenging and pressurized technology use. Consequently, users may perceive the DDM as unfit for purpose or difficult to use. As such, we propose two hypotheses:

H10: Technostress (TECH) has a negative impact on the perceived usefulness (PU).

H11: Technostress (TECH) has a negative impact on the perceived ease of use (PEOU).

Virtual exhibitions have gained popularity and increased accessibility with the widespread use of the Internet and information communication technology (ICT). Zollo et al. (2021) have categorized digital experiences into four types: sensory, emotional, behavioral, and knowledge-based experiences. According to Venkatesh and Davis (2000), digital experiences play a crucial role in shaping users' attitudes, intentions, and behaviors when interacting with technology. For instance, the digitization of museums significantly facilitates communication between visitors and collections (Li et al., 2012). Building on Zollo's framework (2021), we argue that online digital museums enhance users' digital experience through technological advancements, influencing attitudes towards usage and behavioral intentions. Thus, it can be reasonably predicted that users who perceive the DDM as providing an enriched digital experience are likely to develop a positive attitude towards it and continue using it. Accordingly, we propose the following hypotheses:

H12: Digital experience (DE) positively impacts attitude (ATT).

H13: Digital experience (DE) has a positive impact on the behavioral intention (BI).

In summary, we formulated a research framework outlining the attitudes and behavioral intentions of users toward the DDM, drawing upon the TAM and relevant literature, as illustrated in Figure 1.

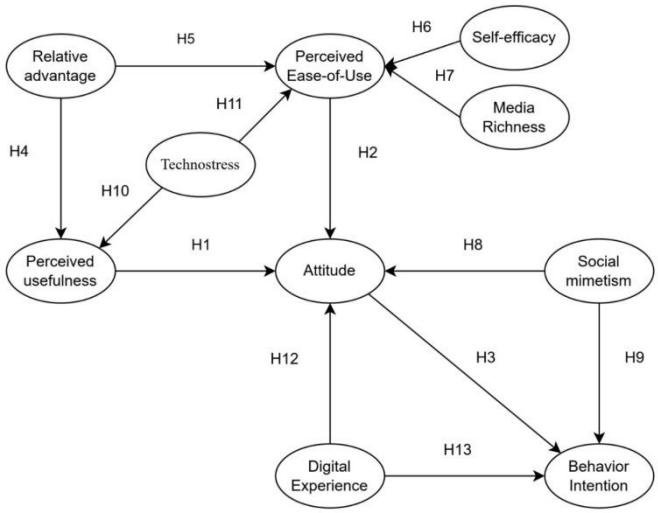

Figure 1. Research model

4. Methodologies

4.1 Stimulus Websites

This study focuses on Dunhuang Digital Museum (DDM), known for its free online viewing and learning features. It delves into Dunhuang culture, recognized for its rich history. The government's emphasis on protecting digital intangible heritage has prompted responses from art galleries and museums. In 2020, the collaboration between the Dunhuang Academy, People's Daily New Media, and Tencent resulted in the launch of "Virtual Tour of Dunhuang", an immersive mini-program. DDM was chosen due to its rational website design, diverse functions, and aesthetic features. Utilizing digital and gaming technologies to create a virtual Sutra Cave, it achieves a highly accurate reproduction, engaging users interactively. The museum employs various formats, including video, audio, images, interactive games, and text, to present historical relics, vividly restoring cultural artifacts' original appearance and enriching the experience of national culture (Song, 2023).

4.2 Questionnaire Design

At the beginning of the questionnaire, we provided participants with an explanation of the purpose of the study, clarifying that the research results are solely for academic research purposes, and addressing issues such as data confidentiality. Participants were directed to the WeChat Mini Program "Virtual Tour of Dunhuang" through a link, where they were asked to explore the DDM on their own for a period of time before proceeding to answer the questionnaire. Figure 2 illustrates a partial interface of the DDM (screenshot from the "Virtual Tour of Dunhuang"), showcasing textual, audio, visual, and video content, as well as a 3D immersive tour experience based on virtual reality technology.

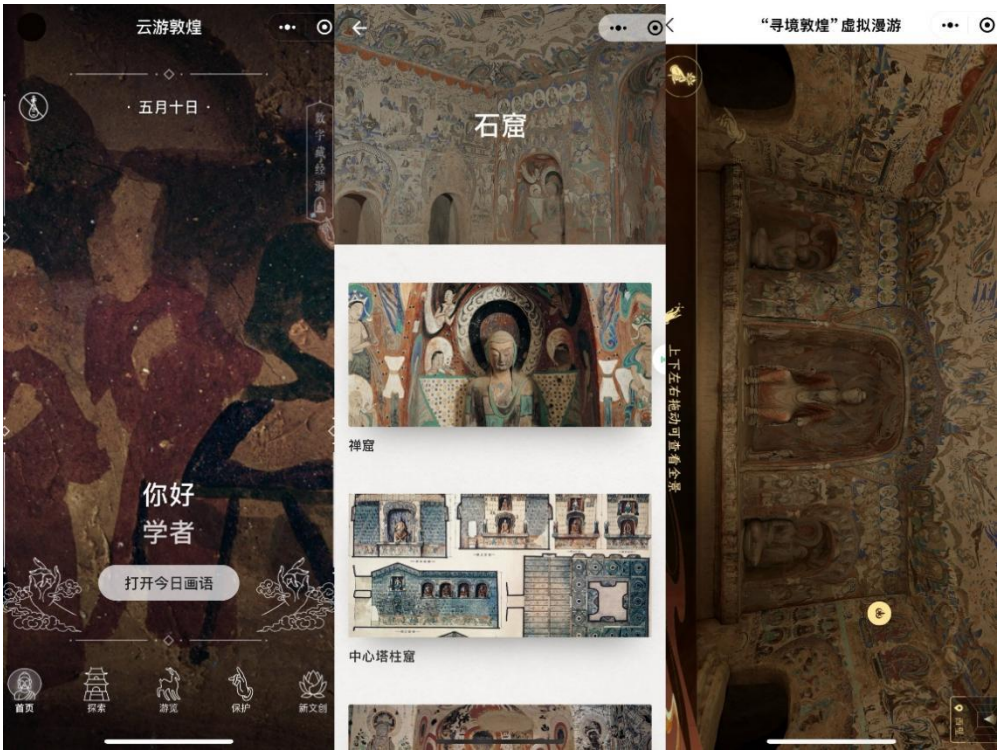

Figure 2. Partial Interface Display of the Dunhuang Digital Museum

To ensure the questionnaire's responsiveness and reliability, an initial question was formulated: "Have you completed exploring the Dunhuang Digital Museum?" If the response is negative, the questionnaire is deemed invalid. The first section of the questionnaire focuses on determining the demographic characteristics of respondents, including gender, age, education, and other basic personal information. The second section delves into variables, consisting of 31 questions corresponding to the 10 variables outlined in the model.

To gauge the structure of the proposed research model, we employed the questionnaire survey method, referencing and modifying items from previous relevant studies. All items were assessed using a 5-point Likert scale (Likert, 1932). Table 2 presents the questionnaire items along with their respective data sources. Before publication, the questionnaire underwent pre-answering by 20 students, and consultation with two experts in the relevant field was conducted. The feedback received prompted adjustments to the number of questions and the

classification methodology employed. The final questionnaire, encompassing various sections that allow users to explore specific aspects of the website, will be distributed on a large scale.

Table 2. Measurements and Sources

Construct	Indicator	Description	References
Perceived Usefulness (PU)	PU1	Using the DDM improves my academic or research performance.	Davis et al (1989)
	PU2	Using the DDM improves the efficiency of my access to resources.	
	PU3	Using the DDM can get what I want knowledge or information.	
Perceived Ease of Use (PEOU)	PEOU1	I find interacting with the DDM to be clear and understandable.	Venkatesh & Davis (2000)
	PEOU2	I find interacting with the DDM requires little of my mental effort.	
	PEOU3	Overall, I find the DDM is easy to use for me.	
Attitude (ATT)	ATT1	Using the DDM is a good method.	Moon & Kim (2001)
	ATT2	Using the DDM is a wise idea.	
	ATT3	Using the DDM would be pleasant.	
Behavior Intention (BI)	BI1	I intend to increase my use of the DDM in the future.	Moon and Kim (2001); Yu et al. (2013)
	BI2	I would strongly recommend others to use DDM.	
	BI3	For future work I would use the DDM.	
Technostress (TECH)	TECH1	I feel tired from using technology.	Verkijika (2019)
	TECH2	Interacting all day with technology is a strain for me.	
	TECH3	I feel burned out from using mobile technology to visit the digital museum.	
Relative advantage (RA)	RA1	Using DDM is relatively faster than visiting offline Dunhuang Museum.	Moore & Benbasat (1991); Karahanna et al. (1999)
	RA2	Using DDM is relatively convenience than isiting offline Dunhuang Museum.	
	RA3	Using DDM is relatively efficient than visiting offline Dunhuang Museum.	
Media Richness (MR)	MR1	I can use the DDM smoothly.	Hung et al. (2016)
	MR2	The DDM provides not only static information, but also dynamic information.	
	MR3	Videos and animations in the DDM offer rich and diversified instructional methods.	
Social mimetism (SM)	SM1	I would participate in using online digital museums because I see my friends using them.	Abel et al (2016); DiMaggio & Powell (1983)
	SM2	I would participate in using online digital museums because I have a fear of missing this opportunity (FOMO).	
	SM3	I would participate in using online digital museums because it had intrigued my curiosity.	

Construct	Indicator	Description	References
Self-efficacy (SE)	SE1	I would feel comfortable enough to use DDM.	Taylor & Todd (1995); Venkatesh & Davis (2000); Venkatesh et al. (2003)
	SE2	If I wanted to, I could easily use DDM.	
	SE3	I would be able to use DDM even if there is no one around help me.	
Digital experiences (DE)	DE1	The digital technology of DDM left a deep impression on visual or other senses.	Brakus et al. (2009) Zollo et al. (2021)
	DE2	DDM thanks to new technologies became an 'emotional museum'.	
	DE3	During the use of DDM, the interactive form of digital technology engaged me in physical behavior.	
	DE4	Digital technology of the DDM stimulated my curiosity and problem solving.	

4.3 Sample and Data Collection

The questionnaire for this study was distributed through online channels from April to July 2023, yielding 413 responses. Following review, 382 responses were deemed valid, constituting a sufficient sample size for the necessary structural equation modeling (SEM) analysis (Jackson, 2003). The online questionnaire platform facilitated the setup, distribution, and collection of responses. To enhance our sample size, we employed snowball sampling, disseminating the survey through professional websites and social media platforms such as WeChat and QQ. Participation was voluntary, with users allowed to withdraw at any time, limited to one participation per IP address.

Descriptive statistics were obtained using SPSS 26.0, and detailed information is presented in Table 3. Survey participants were evenly split by gender, with 62% male and 38% female. The majority of respondents held a bachelor's degree or higher, with 54.97% falling into this education category. Most participants were in the 18-25 age group, comprising 40.58% of all respondents, consistent with earlier studies (Wu et al., 2021; Zollo et al., 2021), reflecting a demographic more accustomed to accessing information through digital technology. Concerning experience with digital museums, the majority (78.01%) had prior exposure, affirming that users familiar with digital museums are more predisposed to explore additional digital museum offerings.

Table 3. Demographic Information of Respondents

Characteristic	Variable	Number	Percent (%)
Gender	Male	235	62.00
	Female	147	38.00
Age (years)	＜18	50	13.09
	18-25	155	40.58
	26-35	99	25.92
	36-45	57	14.92
	＞45	21	5.50
Education	Junior college or below	172	45.03
	Bachelor degree	189	49.48
	Master's degree	19	4.97
	Ph.D. degree	2	0.52
Experiences of digital museum	Yes	298	78.01
	No	84	21.99

5. Results

5.1 Analysis of Reliability

The reliability of the questionnaire data was assessed using the SPSS 26.0 software. Project reliability is assessed by evaluating the potential factors of each project, with a minimum threshold of 0.70 for load, greater than 0.4 for CITC value and the absence of significant increase in Cronbach's α after wiping out random items. Table 4 shows a loading coefficient of over 0.70 for all items, thus concluding good reliability.

5.2 Exploratory Factor Analysis

In this study, exploratory factor analysis (EFA) was used to test the unity of each construct. The results show that each construction can only propose one factor using the principal component analysis method. Moreover, the factor's eigenvalue exceeded 1, providing conclusive evidence for the good single construct of this dataset (Kohli et al., 1998). The KMO values were all above 0.6, and the significance of the Bartlett sphere test was less than 0.05, indicating a significant correlation among the different constructions. Therefore, the data is suitable for exploratory factor analysis. Table 5 displays the results of the exploratory factor analysis.

Table 4. Reliability and Convergent Validity

Construct	Item	Corrected Item-to-Total Correlation(CITC)	Cronbach's αafter Deletion	Cronbach's α
PEOU	PEOU1	0.682	0.721	0.812
	PEOU2	0.614	0.790	
	PEOU3	0.691	0.712	
PU	PU1	0.692	0.755	0.828
	PU2	0.683	0.764	
	PU3	0.68	0.767	
TECH	TECH1	0.687	0.736	0.819
	TECH2	0.681	0.744	
	TECH3	0.651	0.772	
SE	SE1	0.641	0.745	0.805
	SE2	0.663	0.721	
	SE3	0.652	0.734	
RA	RA1	0.709	0.773	0.840
	RA2	0.704	0.777	
	RA3	0.697	0.784	
MR	MR1	0.692	0.759	0.829
	MR2	0.683	0.768	
	MR3	0.686	0.764	
SM	SM1	0.707	0.74	0.828
	SM2	0.655	0.791	
	SM3	0.693	0.754	
ATT	ATT1	0.621	0.731	0.792
	ATT2	0.644	0.706	
	ATT3	0.636	0.715	
BI	BI1	0.686	0.732	0.817
	BI2	0.651	0.767	
	BI3	0.671	0.746	
DE	DE1	0.73	0.771	0.840
	DE2	0.672	0.797	
	DE3	0.657	0.804	
	DE4	0.632	0.814	

Table 5. Results of KMO and Bartlett Sphere Test

Construct	KMO	Item	Factor loadings	Commonality	Eigenvalue	Total variation explained%
PEOU	0.706	PEOU1	0.865	0.749	2.181	72.684
		PEOU2	0.821	0.674		
		PEOU3	0.871	0.758		
PU	0.723	PU1	0.867	0.751	2.231	74.371
		PU2	0.861	0.742		
		PU3	0.859	0.738		
TECH	0.717	TECH1	0.866	0.750	2.205	73.491
		TECH2	0.862	0.743		
		TECH3	0.844	0.712		
SE	0.713	SE1	0.841	0.708	2.160	71.987

Construct	KMO	Item	Factor loadings	Commonality	Eigenvalue	Total variation explained%
		SE2	0.856	0.732		0.805
		SE3	0.849	0.72		
		RA1	0.873	0.763		
RA	0.728	RA2	0.871	0.759	2.272	75.749
		RA3	0.867	0.751		
		MR1	0.866	0.750		
MR	0.723	MR2	0.861	0.741	2.236	74.517
		MR3	0.863	0.745		
		SM1	0.876	0.767		
SM	0.718	SM2	0.844	0.712	2.231	74.378
		SM3	0.868	0.753		
		ATT1	0.832	0.693		
ATT	0.708	ATT2	0.847	0.718	2.119	70.641
		ATT3	0.842	0.709		
		BI1	0.866	0.750		
BI	0.717	BI2	0.844	0.712	2.197	73.241
		BI3	0.857	0.735		
		DE1	0.862	0.742		
DE	0.814	DE2	0.822	0.676	2.702	67.550
		DE3	0.811	0.658		
		DE4	0.791	0.626		

5.3 Confirmatory Factor Analysis

AMOS 24.0 software was utilized to examine the convergence validity and discriminant validity of each potential variable. Table 6 shows that all the testing criteria were met, as indicated by the standardized load factor value being above 0.5. This shows a cross-reference relationship between all test items and the convergence validity factor, indicating good measurement items. Additionally, the AVE value for each factor was above 0.5, and the CR value was above 0.7, indicating good composite reliability. The square root of the AVE (value on the diagonal) for each latent variable exceeds the correlation coefficient of the latent variable, demonstrated in Table 7. This confirms the strong discriminant validity of the data.

Table 6. Reliability and convergent validity

Construct	Item	Unstd.	S.E.	T-value	P.	std.	SMC	1-SMC	AVE	CR
	PEOU1	1	-	-	-	0.800	0.640	0.360		
PEOU	PEOU2	0.871	0.066	13.128	***	0.699	0.490	0.510	0.595	0.814
	PEOU3	1.049	0.071	14.774	***	0.810	0.660	0.340		
	PU1	1.000	-	-	-	0.780	0.610	0.390		
PU	PU2	1.000	0.067	14.817	***	0.785	0.620	0.380	0.615	0.828
	PU3	0.985	0.066	14.877	***	0.789	0.620	0.380		
	TECH1	1.000	-	-	-	0.793	0.630	0.370		
TECH	TECH2	0.913	0.062	14.827	***	0.789	0.620	0.380	0.603	0.820
	TECH3	0.894	0.063	14.148	***	0.747	0.560	0.440		
	SE1	1.000	-	-	-	0.749	0.560	0.440		
SE	SE2	1.05	0.076	13.747	***	0.788	0.620	0.380	0.580	0.805
	SE3	0.944	0.071	13.215	***	0.747	0.560	0.440		
	RA1	1.000	-	-	-	0.803	0.640	0.360		
RA	RA2	1.019	0.064	15.855	***	0.805	0.650	0.350	0.636	0.840
	RA3	0.992	0.064	15.503	***	0.785	0.620	0.380		
	MR1	1.000	-	-	-	0.79	0.620	0.380		
MR	MR2	0.986	0.065	15.096	***	0.792	0.630	0.370	0.618	0.829
	MR3	0.963	0.065	14.849	***	0.777	0.600	0.400		
	SM1	1.000	-	-	-	0.806	0.650	0.350		
SM	SM2	0.929	0.063	14.811	***	0.764	0.580	0.420	0.617	0.829

Construct	Item	Unstd.	S.E.	T-value	P.	std.	SMC	1-SMC	AVE	CR
	SM3	0.971	0.064	15.182	***	0.786	0.620	0.380		
	ATT1	1.000	-	-	-	0.74	0.550	0.450		
ATT	ATT2	1.087	0.085	12.715	***	0.762	0.580	0.420	0.560	0.792
	ATT3	1.029	0.082	12.524	***	0.743	0.550	0.450		
	BI1	1.000	-	-	-	0.779	0.610	0.390		
BI	BI2	0.980	0.071	13.891	***	0.745	0.560	0.440	0.599	0.817
	BI3	1.064	0.072	14.680	***	0.797	0.640	0.360		
	DE1	1.000	-	-	-	0.825	0.680	0.320		
	DE2	0.876	0.058	15.198	***	0.755	0.570	0.430		
DE	DE3	0.831	0.056	14.775	***	0.736	0.540	0.460	0.570	0.841
	DE4	0.806	0.058	13.886	***	0.697	0.490	0.510		

Table 7. Correlation matrix and AVE

	PEOU	PU	TECH	SE	RA	MR	SM	ATT	BI	DE
PEOU	0.771									
PU	0.423	0.785								
TECH	-0.357	-0.448	0.777							
SE	0.437	0.482	-0.434	0.762						
RA	0.428	0.467	-0.474	0.429	0.798					
MR	0.444	0.491	-0.407	0.446	0.424	0.786				
SM	0.379	0.464	-0.424	0.433	0.414	0.500	0.786			
ATT	0.368	0.413	-0.41	0.360	0.400	0.406	0.412	0.748		
BI	0.347	0.415	-0.478	0.430	0.513	0.448	0.454	0.396	0.774	
DE	0.372	0.402	-0.447	0.413	0.402	0.383	0.418	0.376	0.370	0.755

5.4 Model Analysis

The study analyzed the data using AMOS 24. The esthetic-skewness criterion was emphasized by Byrne, Hair et al., and Kline. Normalized chi-squares, chi-squares per degree of freedom, normalized fit index (NFI), goodness of Fit Index (GFI), Tuck-Lewis coefficient (TLI), comparative fit index (CFI), incremental fit index (IFI), and root-mean-square error of approximation (RMSEA) are all tools available to evaluate model estimate procedures, as outlined in Table 8. The fitting results and model indicators demonstrate CMIN/DF=1.317<3, with an RMSEA of 0.029<0.08, confirming the reference standards, the hypothetical model established in this study is well fitted.

Table 8. Summary of goodness fit indices for the measurement model

	$\chi2$	df	$\chi2$/df	GFI	RMSEA	TLI	CFI	NFI	IFI
Common indices	0.771								
Judgment criteria	-	-	<3	>0.9	<0.08	>0.9	>0.9	>0.9	>0.9
Value	534.841	406	1.317	0.918	0.029	0.973	0.977	0.911	0.977

5.5 Structural Model Analysis

The path coefficient of the structural equation indicates the correlation and impact of each path within the model. Table 9 displays the standardized effect values, while Figure 2 illustrates the interplay among the variables in the structural model. The research findings indicate that there is no significant correlation between TECH and PEOU, suggesting that TECH has no influence on PEOU, while the remaining paths of influence demonstrate significance (the specific coefficients and significances have been extensively presented in Table 9).

Table 9. Hypothesis test results

DV		IV	Label	Estimate	S.E.	C.R.	P	Std.	Result
ATT	<---	PU	H1	0.214	0.059	3.597	***	0.240	Supported
ATT	<---	PEOU	H2	0.166	0.061	2.726	0.006	0.183	Supported
BI	<---	ATT	H3	0.243	0.08	3.026	0.002	0.210	Supported
PU	<---	RA	H4	0.380	0.068	5.561	***	0.391	Supported
PEOU	<---	RA	H5	0.203	0.072	2.810	0.005	0.211	Supported
PEOU	<---	SE	H6	0.268	0.084	3.197	0.001	0.249	Supported
PEOU	<---	MR	H7	0.255	0.073	3.475	***	0.255	Supported
ATT	<---	SM	H8	0.215	0.065	3.308	***	0.243	Supported
BI	<---	SM	H9	0.405	0.074	5.459	***	0.395	Supported
PU	<---	TECH	H10	-0.404	0.077	-5.216	***	-0.370	Supported
PEOU	<---	TECH	H11	-0.083	0.082	-1.024	0.306	-0.078	Not supported
ATT	<---	DE	H12	0.164	0.070	2.346	0.019	0.161	Supported
BI	<---	DE	H13	0.221	0.077	2.856	0.004	0.188	Supported

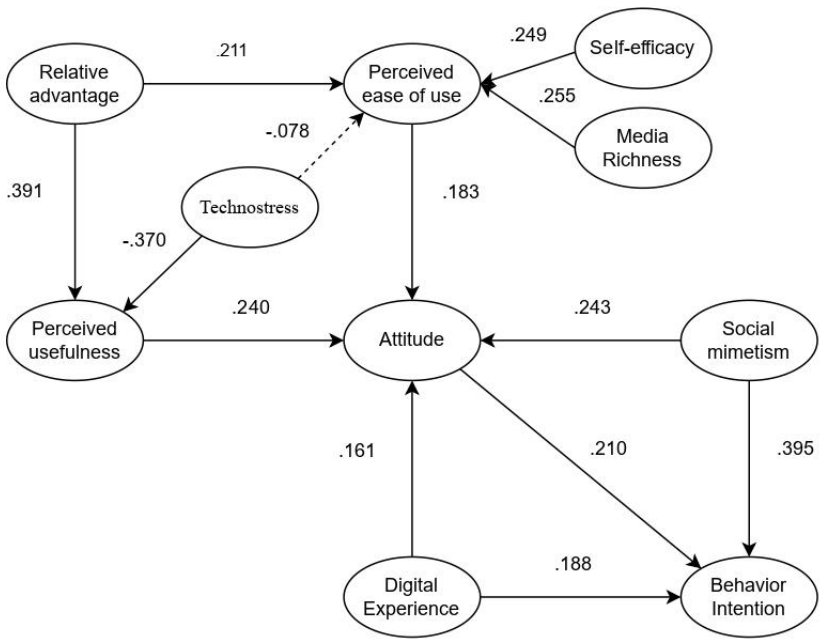

Figure 2. Results for the proposed model

6. Discussions

The digital museum has revolutionized the conventional physical browsing paradigm. However, owing to technological barriers and limitations, it imparts distinct usage experiences to users from diverse social backgrounds, profoundly influencing their future inclination towards digital museums (Fuentes-Moraleda et al., 2021; Zollo et al., 2021). Consequently, a comprehensive investigation into users' value assessments of digital museums and their intent to sustain usage becomes pivotal in the development of these digital cultural institutions. In contrast to the traditional Dunhuang Museum, the digitization of the Digital Dunhuang Museum signifies the transformation of physical artifacts into virtual representations within cyberspace (Song, 2023). This transcendence of temporal and spatial constraints, coupled with the infusion of a gamified narrative depicting artifact history, enhances the user experience significantly.

While extensive research has explored the impact of museum websites on visitor behavior, limited studies scrutinize the consequences of digitizing thematic museum websites on visitors' browsing propensities, encompassing attitudes, intentions, and persistent usage behaviors. This study employed structural equation modeling to assess the proposed model and the 13 hypotheses. The results indicate that all proposed hypotheses were validated except for hypothesis 11. In summary, we have contributed to a deeper understanding in the academic community of the adoption issues of digital museums by expanding the TAM model. Next, we will discuss the results in relation to relevant studies.

First, perceived usefulness (PU) and perceived ease of use (PEOU) are crucial factors influencing users' attitudes toward using the DDM. This aligns with previous research findings on digital museums (Hung et al., 2016; Wu, 2022). To enhance positive user experiences, digital museums should prioritize providing accessible and user-friendly information. It indicates a substantial positive correlation between users' attitudes (ATT) towards the DDM and their behavioral intention (BI). This finding is consistent with prior research using the TAM model, suggesting that higher user satisfaction leads to higher evaluations, thereby strengthening their intention to use this resource.

Second, relative advantage (RA) has a positive impact on both the perceived usefulness (PU) and perceived ease of use (PEOU) of the DDM. The digitization of museums not only increases visitor frequency but also diversifies the interaction formats between museums and visitors. As some studies have pointed out, the development of digital museums transcends traditional visiting methods, bringing about perceived usefulness and ease of use (Shi et al., 2023; Wu et al., 2021).

Third, H5, H6, and H7 collectively assert that relative advantage (RA), self-efficacy (SE), and media richness (MR) positively affect the perceived ease of use (PEOU) of the DDM. This is consistent with the findings of relevant literature and validates the conclusions in a new context (Huang, 2018; Hsiao, 2017). H8 and H9 are validated, indicating that social mimetism (SM) has a positive effect on attitudes (ATT) and behavioral intentions (BI) toward the DDM. Social mimetism encourages positive attitudes and intentions toward immersive exhibitions. Individuals are drawn to the DDM out of curiosity or fear of missing out on the knowledge and materials accessed by their peers, resulting in positive intentions to use the museum. This conclusion aligns with previous findings of Abel et al. (2016) and Khalil et al. (2023).

Finally, it confirms that technostress (TECH) has a negative correlation with users' perceived usefulness (PU) of the DDM. This is consistent with viewpoints from relevant literature in the field of technostress (Torres et al., 2021; Verkijika, 2019). Digital museums, as a new technology, to some extent, introduce usage pressure to users, thereby reducing their perception of usefulness. However, H11 is invalidated, indicating no significant relationship between technostress (TECH) and perceived ease of use (PEOU) when using the DDM. This outcome aligns with Wu et al.'s (2022) findings but contrasts with Heponiemi et al.'s (2021) results. This inconsistency may arise from dissimilarities in users' digital museum expertise. The age group primarily between 18 and 25 has grown up in a proficient technology milieu, demonstrating competence in digital technology operations. Additionally, digital experience (DE) positively influences both attitudes (ATT) and behavioral intentions (BI) within the DDM. This finding is similar to that of Zollo et al. (2021), whose research indicates that the digital experience of digital museums can enhance visitors' identification with the museum, predict positive attitudes, and influence behavioral intentions.

Based on the conclusions of this study, several potentially useful recommendations are proposed to facilitate the development and better adoption of digital museums. Firstly, digital museums should prioritize enhancing user experience, which involves improving interface design, increasing interactivity, and providing rich digital experiences. By optimizing user experience, attitudes towards and adoption intentions of digital museums can be strengthened. Additionally, social mimicry emerges as a significant factor influencing user behavioral intentions. Digital museums can leverage social media platforms and other means to bolster social influence, attracting more users to engage with and share their experiences. Emphasizing the advantages of digital museums over traditional ones and fostering users' confidence in digital technology are also crucial. This can be achieved by showcasing the convenience, diversity, and accessibility of digital museums relative to their traditional counterparts. Lastly, in the design and development process, efforts should be made to mitigate the negative impact of technological stress on user adoption intentions. This may involve providing simple and user-friendly interfaces, clear navigation and guidance, as well as prompt technical support.

7. Conclusions

This study examines the user behavior intention of the Dunhuang Digital Museum based on the technology acceptance model. The findings indicate that attitude, social mimetism, and digital experience are crucial factors

influencing user behavior intention. Attitude, serving as the core factor, is positively influenced by perceived ease of use, perceived usefulness, social mimetism, and digital experience. Relative advantage, self-efficacy, and media richness have positive effects on perceived ease of use. Moreover, relative advantage positively impacts perceived usefulness. However, technostress exerts a negative influence on perceived usefulness, while its effect on perceived ease of use is not statistically significant.

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Authors contributions

Yutong Chen were responsible for study design. Xinyi Chen was responsible for data collection. Yutong Chen drafted the manuscript and Xinyi Chen revised it. All authors read and approved the final manuscript.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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