Virtual presence and enjoyment as mediators between interaction quality and continuance intention in China's smart museums

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ABSTRACT

This study examined how perceived virtual presence and perceived enjoyment mediate the relationship between interaction quality and continuance intention in China's smart museums. Based on the Technology Acceptance Model (TAM), the study proposed an extended framework that includes experiential factors to explain sustained user engagement with digital cultural technologies. Data were collected through a quantitative survey of 464 museum visitors and analyzed using partial least squares structural equation modeling (PLS-SEM). The findings show that interaction quality has a significant positive effect on both perceived virtual presence and perceived enjoyment. These two factors, in turn, positively influence continuance intention. Among the mediators, perceived enjoyment had the strongest effect, while perceived virtual presence contributed to continuance intention both directly and indirectly. The model explained 53.9% of the variance in continuance intention, highlighting the joint role of technological and psychological factors in post-adoption behavior. This study extends the TAM in immersive cultural contexts and provides practical insights for designing smart museum technologies that encourage long-term visitor engagement.

1. Introduction

With the development of modern technology, the museum's presentation techniques have also seen a revolution. This phenomenon has been especially pronounced in the context of China, which has given birth to 'smart museums', which are distinguished by their capacity to digitally augment physical exhibits (Wang et al., 2023). These smart museums employ augmented reality (AR), virtual reality (VR), artificial intelligence (AI), and the Internet of Things (IoT) to provide actively engaging and interactive experiences to visitors (Serravalle et al., 2019). While societies are gradually resuming in-person engagements, the expectations of museum users have fundamentally changed. Today, the integration of technology is deemed a necessity rather than a complement to a museum visit.

This study focuses on an area formed by merging museum studies, information systems, and consumer behavior analysis. It investigates how different cultural institutions employ digital technologies to manage visitor experiences and how these technologies influence future visits. Most prior work has addressed components related to the adoption of smart technologies in museums, but there is a lack of more comprehensive frameworks that address the reasons underlying visitor retention. Further research has focused on the aspects of smart museums, with a focus on the application of interactive technologies (Balducci et al., 2020), the measurement of visitor engagement (López-Martínez et al., 2020), and the preservation of cultural heritage via digitization (Todorova-Ekmekci, 2021). This research focuses on the positive impacts of digital technologies on museums' operational processes and outcomes and, to a certain extent, visitor satisfaction. Not everything has been captured, and gaps still exist. First, the psychological

factors that mediate the technology–visitor outcome relationship are seldom addressed. Second, while interaction quality is an essential component in most digital settings, its influence in museums is unknown. Third, smart museum studies tend to analyze the primary use case scenario and overlook the long-term vision, leading to a lack of sustainable purposes. Finally, the rapidly expanding smart museum market emerging from China presents a need flagged by foreign scholars despite leading innovative developments.

This study focuses on the previously identified gaps by designing and empirically validating a case study on the impact of interaction quality on smart museum visitors' revisit intelligence. This study expands the TAM by incorporating telepresence and perceived enjoyment as mediators in the relationship between interaction quality and continuance intention within smart museums. This study is important because of its three main contributions. First, it incorporates telepresence and perceived enjoyment as critical mediating factors of technology acceptance models in cultural institution contexts, thereby extending its boundaries. Second, it addresses the lack of empirical data from the smart museum ecosystem in China, providing insights from a frontrunner in the digitalization of museums. Third, the results provide global museum practitioners with actionable strategies in the context of post-pandemic recovery planning that aim toward sustainable visitor stimulation through purposeful investments in digital technology.

To address these research gaps, this study poses two primary research questions: (1) How does the quality of interaction with smart technologies in museums influence visitors' perceived virtual presence, perceived enjoyment, and ultimately their continuance intention? (2) Do these relationships differ among visitor segments with varying technological literacy and museum visitation frequencies? Methodologically, this research adopts a quantitative approach in which questionnaire surveys are administered to visitors of smart museums in China. The TAM serves as the primary theoretical framework for developing an understanding of visitor engagement with immersive technologies in museum settings.

This study makes several theoretical and practical contributions. Theoretically, it extends our understanding of digital experience continuance by identifying the specific pathways through which interaction quality influences visitor retention in cultural institutions. It also refines the concept of telepresence within smart museum environments, distinguishing it from related constructs such as immersion and engagement. Practically, the findings help museum curators and technology designers create more effective digital experiences that not only attract visitors but also encourage repeated engagement.

Additionally, this research provides valuable insights for cultural policy makers in China and beyond as they develop frameworks to support sustainable digital transformation in the cultural heritage sector.

2. Theoretical framework and hypothesis development

Originally, the TAM focused on computer behavior within workplaces; since then, it has been modified to address new contexts, including the adoption of new technologies by cultural heritage institutions embracing digital transformation. TAM relies on two factors, perceived usefulness and perceived ease of use, as the primary determinants of technology adoption attitudes, intentions, and actual use of the system.

TAM is useful in analyzing the concept of visitor engagement with new technologies in smart museums. Unlike the traditional "object-centric" museums that predominate the landscape, smart museums are a shift towards "experience-centric" museums, where interactive spatial multimedia computer elements augment the visitor experience by enabling enriched interactions (Shi et al., 2023; YiFei and Othman, 2024). Understanding how users perceive and respond to these technological extremes shifts innovations, which is why TAM is suitable for this research.

In recent years, researchers have extended the reach of TAM to incorporate the peculiar characteristics of museums and their visitors. Zollo et al. (2022) introduced social media and digital propensity as additions to loyalty and satisfaction towards digital museums. In the same manner, Hung et al. (2013) maintained that personal innovativeness, computer self-efficacy, and systems' media richness were foundational to the adoption of such technologies by these museums. However, these studies have a greater balance between the focus of the technological aspects and personal factors on visitor technology acceptance.

The integration of smart technologies such as augmented reality (AR) and virtual reality (VR) devices into museum infrastructure and services has resulted in some sophisticated transformations in the TAM. Li et al. (2024) examined the TAM components concerning museum visitors' acceptability of using wearable AR gadgets and found that their aesthetics and the level of technological preparedness were powerful predictors. Khalil et al. (2024) described social mimetism and perceived playfulness as newly important predictors of attitudes towards participation in immersive exhibitions. These studies highlight how the multisensory and social aspects of museum experiences interact with enabling technologies to provoke a range of visitor responses.

For this analysis, we considered several theoretical frameworks before selecting an expanded TAM for our study. The Unified Theory of Acceptance and Use of Technology (UTAUT2) (Venkatesh et al., 2012) offers advantages for hedonic contexts through its inclusion of constructs such as hedonic motivation and habit. However, we

ultimately expanded the TAM to incorporate interaction quality as a formative antecedent variable, with perceived virtual presence and perceived enjoyment as mediating variables, both leading directly to continuance intention. Our decision to use TAM over UTAUT2 was based on three key considerations: (1) TAM's parsimony and adaptability to experiential contexts, (2) the substantial body of literature validating TAM in cultural heritage settings, and (3) our focus on psychological mediators rather than the broader social and facilitating conditions emphasized in UTAUT2.

While the original TAM includes attitudes toward use as a mediating variable between perceptions and behavioral intentions, this study purposefully excludes this construction for several reasons. First, recent TAM investigations within hedonic contexts have identified attitudes as having considerably limited explanatory power beyond perceptions in experience-driven ecosystems (Shi et al., 2023). Second, explorations by Khalil et al. (2024) and Li et al. (2024) posit that within immersive technology frameworks, enjoyment and presence as perceptual factors may influence behavioral intention directly without attitudinal mediation. Third, research within the digital heritage domains indicates that the difference between enjoyment and favorable attitudes tends to fade in recreational contexts, resulting in overlap (YiFei and Othman, 2024). The relevance of TAM's attitudes to the context of smart museums is limited; thus, their omission is a beneficial simplification. These findings reinforce the conclusions of Shi et al. (2023), who argued that interaction quality directly influences user satisfaction and digital museum continuance intention. Perceived enjoyment captures the hedonic benefits gained through technologies in smart museums, while perceived virtual presence provides the elements of immersion.

The framework, as proposed, has distinctive value, as it addresses not only acceptance but also specific continuance intention related to smart museum technologies, which is vital for sustained engagement. This study examines the driving factors behind smart museum technologies and visitors' continued engagement intentions, focusing on interaction quality, perceived virtual presence, perceived enjoyment, and attitudes toward use, thus enhancing the literature on technology acceptance in cultural heritage contexts.

The relationship between interaction quality and perceived virtual presence represents a crucial aspect of visitor experiences in smart museums. We define interaction quality as the degree to which a technological system facilitates responsive and engaging interactions between users and digital content. Perceived virtual presence refers to the psychological state in which technology-mediated objects are experienced as real, creating an immersive sensory or cognitive experience (Munnukka et al., 2022). In smart museums, where technology mediates visitors' engagement with cultural artifacts through virtual or augmented environments, high-quality interactions are likely to enhance visitors' sense of presence within these digital spaces.

The existence of this proposed relationship is supported by empirical evidence from several other related domains. The use of virtual service assistants has shown that perceived anthropomorphism and social presence positively impact recommendation trust and quality. This observation supports the argument that perceived interaction quality contributes to a sense of virtual presence (Munnukka et al., 2022). Other research on the communication of virtual teams has demonstrated that high social presence and richness of the media are associated with high interaction quality (Andres, 2002). These observations support the common understanding that users who partake in high-quality interactions are likely to have a stronger sense of virtual presence.

The bond is strengthened by research carried out in virtual reality environments, where the sensation of presence has been noted as an important element regarding usability. Sun et al. (2015) noted that both immersion and involvement generate value towards usability, adding to the bidirectional perception of 'provided interaction' and enhancing the quality of presence. Such a situation is particularly true in the case of smart museums, which are intended to use technologies to facilitate the visitors' interaction with cultural artefacts. In Toward Us, planners emphasized smart museums.

Presence is claimed to be significantly impacted by interactivity, according to some recent studies. Per Al-Geitany et al. (2023), perceived interactivity within virtual conferences positively affects the perceptions of quality and the intention to act positively. Simultaneously, Guo et al. (2024) demonstrated that interactivity within VR and AR environments determines the level of presence, which subsequently impacts user satisfaction and behavioral intentions. All these contributions apply to the setting up of smart museums, where exhibits are developed to encourage active engagement and foster immersion.

Based on the theoretical foundations and empirical evidence, this study proposes the following:

H1: Interaction quality positively influences perceived virtual presence in smart museum environments.

The link between interaction quality and perceived enjoyment is, likewise, another important pathway through which technologies in smart museums impact their visitors' experiences. Perceived enjoyment is defined as the level of enjoyment associated with the use of a particular technology in and of itself, separate from any outcomes that are expected to result from its use. In smart museums, which rely on visitors' experiences being predominantly hedonic, visitors' enjoyment of

the museum is likely to be influenced by the interactions they have with the digital technologies on display.

There is strong empirical evidence to support this proposed relationship. Research conducted by Shi et al. (2025) in the Zisha-ware Digital Museum of China revealed that interaction quality has a significant effect on users' psychological perceptions, including their perceived enjoyment, which, in turn, influences their continuance intention. This finding is useful because it captures the relationship in a setting that is almost identical to the present study, thereby reinforcing the proposed hypothesis.

This interaction is further supported by several studies in different digital contexts. In examining corporate social network services, Seol et al. (2016) demonstrated that social interaction quality affects perceived enjoyment, reinforcing how digitally social environments enhance the user experience. Similarly, Gao and Huang (2024) provided evidence that interaction fluency in omnichannel retail settings enhances perceived enjoyment, which influences intentions to shop. These results seem to indicate that enjoyment is more likely when digital interactions are smooth and engaging.

This interplay between interaction quality and perceived enjoyment is also present in the context of self-service technologies. Kim and Choi (2025) explored the relationship between self-service technology features and interaction quality in customer-to-customer contexts and reported that enjoyment plays a significant role. This suggests a reciprocal relationship in which interaction quality is perceived more positively when enjoyment is present, reinforcing a cycle that may be important in smart museums.

Other studies also support the claim regarding web-based information retrieval systems. van Schaik and Ling (2011) noted that perceived enjoyment is determined by interaction experience, which subsequently hinges on the quality of interaction with computer-based systems. This applies to smart museums, where visitors frequently and interactively seek information about exhibits and cultural artefacts through digital systems.

Based on this theoretical and empirical foundation, this study proposes the following:

H2: Interaction quality positively influences perceived enjoyment in smart museum environments.

The connection between perceived virtual presence and continuance intention contributes to understanding how smart museums' immersive experiences influence visitors' engagement with technologies and their propensity to revisit the venue. Essentially, continuance intention means the conscious decision of users to actively sustain an engagement with a given technology or service beyond its initial adoption. This is most applicable in the case of smart museums, where visitors' sustained engagement is critical to long-term

viability, since managing the belief of virtual presence to enhance intention to return is most vital.

There is strong empirical support for this hypothesized relationship across different immersive technologies. Huang et al. (2021) emphasized the role of presence in virtual reality practice and its relation to engagement with reality for older adults. Their evaluation claimed that interactivity enhances presence and increases the likelihood of repeat usage of VR programs. This is helpful for smart museums seeking to incorporate these features to enhance appeal for diverse age groups.

This connection is strengthened with other works done in the framework of augmented reality. Kabir and Kang (2024a) studied the effects of augmented reality presence on trust and user satisfaction, both central components of continuance intention. The authors noted that high levels of presence tend to foster greater trust, which further increases user retention of the platform. In one of the other studies, Kabir and Kang (2024b) validated the hypothesis that the presence, based on interaction with the platform, is a primary predictor of mobile augmented reality platforms' continuance intention. These findings help to understand the application of AR technologies for enhancing visitors' experiences in smart museums.

The study of virtual worlds heightens the support of this relationship. Hooi and Cho (2017) were interested in self-presence activated by avatar-self similarity (avatar perception as the virtual self) and its relation to continuance intention in virtual worlds. The results revealed that self-awareness and self-presence contribute greatly to the sustained engagement of users in virtual environments. Although smart museums may not use avatars, the importance of inviting and feeling a sense of control over digital content, as discussed in this research, is useful in designing personalized museum experiences.

The connection between virtual presence and continuance intention can be explained by several theoretical mechanisms. First, a strong sense of presence enhances engagement and immersion, thus increasing the value of and desire to use the technology more often. Second, presence enhances the emotional connection to digital content, resulting in visitors wanting to create memorable experiences that they wish to repeat. Third, the presence might reduce the perceived gap between actual and digital experiences, making the use of technology seem more intuitive than effortful, hence reducing friction towards habitual usage.

Based on this theoretical and empirical foundation, this study proposes the following:

H3: Perceived virtual presence positively influences continuance intention in smart museum environments.

The association between perceived enjoyment and continuance intention is a critical component

when analyzing users in hedonic contexts such as smart museums. Perceived enjoyment is the pleasure or satisfaction that users obtain from technology, whereas continuance intention is the user's intention to persist in using the technology after the initial encounter. In smart museums, which aim to make visitor experiences both educational and entertaining, examining the enjoyment factor that influences the intent to return is essential for formulating effective digital engagement frameworks.

The proposed relationship is well documented in a wide range of empirical studies. Notably, Pereira and Tam (2021) studied enjoyment as a factor in the continuance intention of video-on-demand services and discovered that enjoyment has a strong influence on satisfaction, which in turn is a dominant predictor of continuance intention. The lessons learned focus on building digital offerings that visitors enjoy, and satisfaction becomes an incentive to visit again.

The relationship is further substantiated by research focused on digital content platforms. Shiau and Luo (2013) studied blog users and reported that perceived enjoyment, alongside user involvement and user satisfaction, significantly predicts continuance intention. They noted that users who take pleasure from their interactions with digital content are more likely to continue using the content—this principle applies to digital content in smart museums.

Of special concern to the present study is Shi et al.'s (2025) research on the role of perceived enjoyment as a mediator between interaction quality and continuance intention at the Zisha-ware Digital Museum in China. These findings highlight the importance of enjoyment in facilitating user engagement within digital museums, thus offering robust support for the hypothesis in an environment that closely resembles that of the current study.

The relationship between perceived enjoyment and continuance intention is further supported by research on mobile applications. Akdim et al. (2022) evaluated the impact of perceived enjoyment on the continuance intention to use social mobile apps and demonstrated that enjoyment is a crucial factor, especially for hedonic apps such as Instagram. Their findings highlight the importance of enjoyment in contexts where the primary purpose of technology use is pleasure rather than utility, a characteristic shared by many smart museum applications designed to enhance visitor experiences.

The theoretical underpinning of this relationship can be explained through several mechanisms. First, enjoyment represents intrinsic motivation, which is generally more sustainable than extrinsic motivation for continued behavior. Second, positive emotional experiences, such as enjoyment, create psychological attachments to the technology that encourage continued use. Third, enjoyment enhances user satisfaction, which is a well-established predictor of continuance intention in technology acceptance research.

Based on this theoretical and empirical foundation, this study proposes the following:

H4: Perceived enjoyment positively influences continuance intention in smart museum environments.

The link between perceived enjoyment and advanced virtual presence in the context of smart museums highlights an intricate relationship that further elucidates the visitor experience and the psychological processes underlying it. While earlier theories have explained the impacts of perceived interactional quality on both perceived virtual presence and perceived enjoyment, as well as the impacts of these two constructs on continuance intention separately, the link between presence and enjoyment is an issue that needs focused analysis. This explains the degree to which the sense of being engaged within a virtual setting enhances the pleasure associated with the experience, which formulates the essence of smart museums that aim to inform and entertain visitors simultaneously.

Substantial empirical evidence supports this proposed relationship across various virtual environments. Barreda-Ángeles and Hartmann's (2022) analysis, which accelerated the digital adoption of museums, revealed that social presence within virtual reality spaces is predictive of enjoyment, indicating the enhancement of psychological state benefits in virtual spaces. Users who perceive social presence in virtual spaces tend to enjoy themselves more, supporting the hypothesis that presence brings about enjoyment. This is particularly important for smart museums that embed social features into their digital offerings.

The connection is further validated through studies on VR storytelling in cultural heritage contexts. Yang and Zhang (2022) reported that presence in VR storytelling greatly increases enjoyment, demonstrating a direct relationship. Their study suggested that the more users feel present in a narrative virtual environment, the more they enjoy the storytelling session. This impact is directly relevant to smart museums, which often use narratives to capture the attention of visitors around cultural artefacts and historical narrative contexts.

Additional support comes from studies specifically examining virtual presence in cultural heritage applications. Jung et al. (2016) investigated virtual presence in mixed reality experiences at cultural heritage sites and found that heightened presence significantly enhanced visitor enjoyment and satisfaction. Similarly, Hammady et al. (2016) demonstrated that augmented reality applications in museum contexts created stronger feelings of presence that directly correlated with increased enjoyment and engagement with historical content. These museum-specific findings provide robust evidence that the presence-enjoyment relationship is particularly salient in cultural heritage environments. Research on virtual museum environments suggests that enjoyment during

participation may be associated with a stronger sense of perceived presence. When users find the experience enjoyable, they may feel more immersed in the virtual environment. This perspective aligns with the assumptions of the present study, which examines the relationship between user engagement and perceived presence in virtual museum contexts.

This relationship can be explained through several theoretical frameworks. First, presence may enhance enjoyment by bridging the cognitive gap between the user and the virtual content, thus allowing experiences to be more direct and engaging. Second, presence may support the flow experience, which is described as absorption, enjoyment, and intrinsic motivation, by enabling full attention to be focused on the virtual world. Third, presence may enhance virtual experiences, making them more authentic and therefore enjoyable. In the specific context of smart museums, the relationship between perceived virtual presence and perceived enjoyment may be particularly significant due to the cultural

and educational nature of the content. When visitors feel present in a virtual historical environment or connected to a digital representation of a cultural artifact, they may derive greater enjoyment not only from the technological experience but also from the meaningful cultural engagement it facilitates.

Based on this theoretical and empirical foundation, this study proposes the following:

H5: Perceived virtual presence positively influences perceived enjoyment in smart museum environments.

Based on the hypothesis development discussed above, this study proposes a research model that examines how interaction quality influences continuance intention in smart museums through the mediating effects of perceived virtual presence and perceived enjoyment. Fig. 1 presents the conceptual model illustrating the hypothesized relationships.
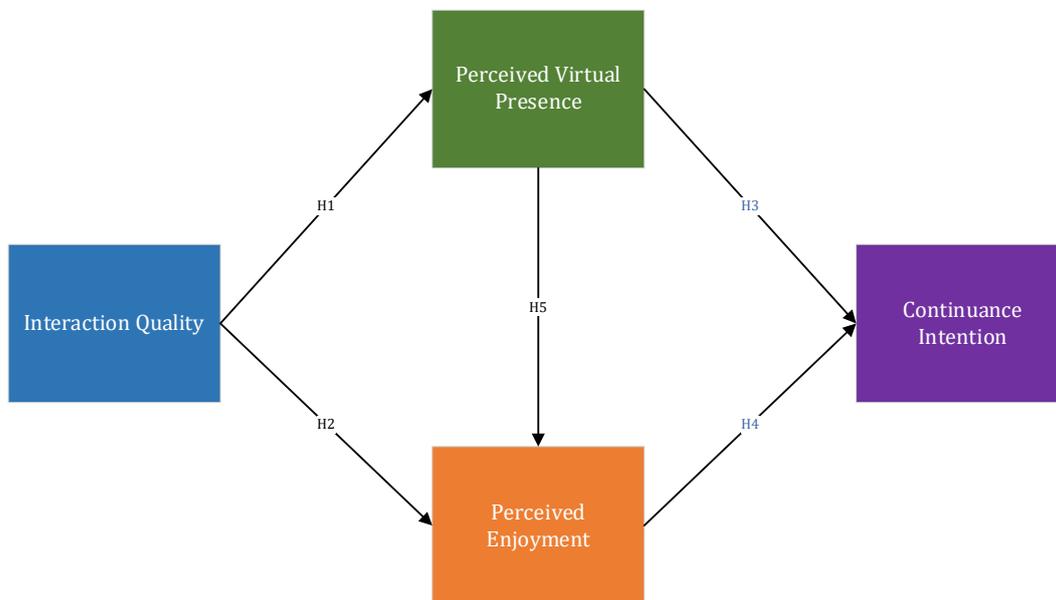

Fig. 1: Research model

Having established our theoretical framework and research hypotheses, we now turn to the methodological approach used to empirically test these relationships. The following section outlines our research design, sampling procedures, measurement instruments, and analytical techniques employed to investigate the proposed model in the context of China's smart museums.

3. Methodology

This study employs a quantitative research approach via a questionnaire survey to examine the relationships among interaction quality, telepresence, perceived enjoyment, and continuance intention in smart museum contexts. A cross-sectional design was selected as appropriate for testing the proposed theoretical framework and hypothesized relationships. The quantitative approach allows for systematic measurement of the

key constructs and enables statistical testing of the hypothesized relationships through structural equation modelling.

The questionnaire was developed based on established scales from the relevant literature and adapted to the smart museum context. To ensure content validity, the survey instrument was initially reviewed by three experts in museum studies and information systems. The final questionnaire consists of demographic information and five-point Likert scale items measuring the four main constructs.

This design aligns with similar studies in technology acceptance research, particularly those examining visitor experiences in digital cultural contexts. The cross-sectional approach enables efficient data collection from a diverse sample of smart museum visitors, providing a snapshot of current visitor perceptions and behavioral intentions across multiple institutions in China. While this

design cannot establish causality definitively, it is suitable for testing the mediating relationships proposed in the theoretical model. Data have been collected from visitors to four major smart museums in China: the Shanghai Museum, Nanjing Museum, Zhejiang Provincial Museum, and Guangdong Provincial Museum. These institutions were selected based on their advanced implementation of smart technologies, geographic distribution across different regions of China, and high visitor traffic, ensuring a diverse and representative sample.

A stratified sampling approach was employed to ensure representation across diverse visitor demographics, complemented by systematic sampling techniques. Research assistants stationed at museum exits first categorized visitors based on observable demographic characteristics (age group and gender) and technology engagement levels. From each stratum, participants were selected using a systematic approach where every third visitor was approached during scheduled time blocks covering different days of the week and times of day. This combined stratified-systematic approach helped mitigate selection bias while ensuring proportional representation across key demographic variables. Additionally, quota controls were implemented to maintain balanced representation of visitors (local residents, domestic tourists, and international visitors). Only visitors who had engaged with at least one smart technology exhibit during their visit were included in the study.

Data collection occurred over a three-month period from August to November 2024, capturing both weekday and weekend visitors as well as domestic and international tourists. The questionnaire was administered via tablet devices, allowing for immediate data capture and reducing data entry errors. To encourage participation, respondents were offered a small museum-themed souvenir upon completion of the survey.

The measurement items for this study were adapted from established research to investigate how telepresence and perceived enjoyment mediate the relationship between interaction quality and continuance intention in smart museums. For our four key variables, the authors carefully selected and modified scales from the relevant literature to ensure appropriate contextualization while maintaining conceptual integrity.

Table 1 presents the four variables, their sources, and the adapted measurement items for our smart museum context. Each variable was measured via three items on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Table 1: Constructs, sources, and measurement items

Variable	Source	Adapted Items
Interaction quality (IQ)	Resnick et al. (2021)	IQ1: The smart museum technology provides good, constructive, and beneficial interactions with cultural exhibits. IQ2: The interactions with smart museum technology are clear and appropriate for understanding cultural content. IQ3: The smart museum technology facilitates smooth and responsive interactions rather than brief or indifferent ones. IQ4: The smart museum technology allows me to interact with exhibits in a way that feels natural and intuitive. IQ5: The smart museum technology provides positive interactions that enhance my understanding of cultural content.
Perceived virtual presence (PVP)	Van Brakel et al. (2023)	PVP1: When using smart museum technology, I feel immersed in the historical or cultural environment being presented. PVP2: The smart museum technology creates a sense that I am transported to different times or places related to the exhibits. PVP3: While using smart museum technology, I feel more connected to the cultural artifacts than through traditional viewing methods. PVP4: I experience a sense of being in the same space as the cultural artifacts when using the smart museum technology. PVP5: The smart museum technology makes me feel mentally involved in the cultural environment being presented.
Perceived enjoyment (PE)	Hasan et al. (2021)	PE1: Using smart museum technology to explore cultural exhibits is enjoyable. PE2: I find the process of interacting with cultural artifacts through smart museum technology to be pleasant. PE3: I have fun engaging with historical and cultural content through smart museum technology. PE4: The experience of using smart museum technology is entertaining regardless of the information gained. PE5: Time passes quickly when I am using smart museum technology to explore exhibits.
Continuance intention (CI)	Chen et al. (2012)	CI1: I intend to continue using smart museum technology for cultural experiences rather than discontinue its use. CI2: My intentions are to continue using smart museum technology for exploring cultural exhibits rather than use traditional methods. CI3: If I could, I would like to continue using smart museum technology for my museum visits in the future. CI4: I will recommend others to use smart museum technology when visiting museums. CI5: I plan to increase my use of smart museum technology in future museum visits.

Data analysis was conducted via SmartPLS 4.0 for partial least squares structural equation modelling. This approach was chosen for its ability to handle complex predictive models and mediating effects in emerging technology contexts. Our analysis followed a two-stage process. First, authors evaluated the measurement model by assessing indicator reliability (outer loadings > 0.7), internal consistency reliability (Cronbach's alpha and composite reliability > 0.7), convergent validity (AVE > 0.5), and discriminant validity (HTMT ratio).

After confirming measurement model validity, the authors analyzed the structural model by examining path coefficients and significance levels

(bootstrapping with 5,000 subsamples). The authors evaluated the mediating effects of perceived virtual presence and perceived enjoyment through specific indirect effects analysis. Additionally, the authors assessed the model's effect sizes (f^2) to determine the impact of each predictor construct.

4. Results

In this study, a total of 464 valid responses were collected. The demographic profile of the respondents reflects a diverse group of museum visitors, primarily concentrated in the younger and middle-aged adult segments. Specifically, 36.9% of the participants were aged 26–35, followed by 32.8% aged 36–45, while those aged 18–25 accounted for 16.6% of the sample. Only a small proportion were older adults aged 46–55 years (9.5%) or 56 years and above (4.3%). The gender distribution was relatively balanced, with 52.6% male and 47.4% female respondents. In terms of museum visiting experience, most participants reported having 1–5 years (39.4%) or 6–10 years (31.9%) of experience, whereas fewer respondents had 11–20 years (15.1%), less than one year (9.5%), or more than 20 years (4.1%) of experience. These demographic characteristics suggest that the majority of the smart museum users in this sample are technologically engaged adults with moderate levels of prior exposure to museum environments,

providing a relevant and representative basis for examining the proposed research model.

As shown in Table 2, the measurement model results demonstrate satisfactory reliability and convergent validity for all the constructs. The Cronbach's alpha values range from 0.840 to 0.883, indicating strong internal consistency. The composite reliability (rho_c) values are all above 0.88, further confirming construct reliability. Additionally, average variance extracted (AVE) values exceed the 0.50 threshold for all the constructs, ranging from 0.616 to 0.684, thereby establishing convergent validity. These results confirm that the measurement scales used in this study are both reliable and valid for assessing interaction quality, telepresence, perceived enjoyment, and continuance intention in the smart museum context.

As shown in Table 3, the results of the Heterotrait–Monotrait ratio (HTMT) confirm adequate discriminant validity among all the constructs in this study. All the HTMT values range from 0.688 to 0.764, well below the conservative threshold of 0.85, indicating that each construct is empirically distinct from the others. This suggests that interaction quality, perceived virtual presence, perceived enjoyment, and continuance intention are conceptually and statistically discriminable in the context of smart museum experiences.

Table 2: Measurement model reliability and convergent validity

Construct	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
Continuance intention	0.883	0.910	0.915	0.684
Interaction quality	0.840	0.845	0.888	0.616
Perceived enjoyment	0.882	0.901	0.915	0.683
Perceived virtual Presence	0.867	0.890	0.905	0.658

Table 3: Discriminant validity assessment using HTMT ratios

Construct pair	HTMT
Interaction quality <-> continuance intention	0.725
Perceived enjoyment <-> continuance intention	0.758
Perceived enjoyment <-> interaction quality	0.728
Perceived virtual presence <-> continuance intention	0.733
Perceived virtual presence <-> interaction quality	0.688
Perceived virtual presence <-> perceived enjoyment	0.764

Table 4 shows that all the examined path relationships are statistically significant at the 0.001 level. Specifically, interaction quality significantly influences continuance intention (β = 0.494, t = 10.552, p < 0.001), indicating a strong direct effect.

Additionally, interaction quality positively affects perceived enjoyment (β = 0.272, t = 4.903, p < 0.001), supporting its role as a driver of hedonic experience in smart museums. Furthermore, perceived virtual presence also has a significant effect on continuance intention (β = 0.204, t = 4.419, p < 0.001), confirming its importance in sustaining visitor engagement. These findings support the proposed relationships in the research model and highlight the critical role of both experiential and perceptual factors in predicting the continued use of smart museum technologies.

Table 4: Structural model path coefficients and significance testing

Structural path	Original sample	Sample mean	Standard deviation	T-statistics	P-values
Interaction quality -> continuance intention	0.494	0.499	0.047	10.552	0.000
Interaction quality -> perceived enjoyment	0.272	0.270	0.056	4.903	0.000
Perceived virtual presence -> continuance intention	0.204	0.201	0.046	4.419	0.000

As shown in Table 5, the f-squared (f^2) analysis reveals that interaction quality has a large effect on perceived virtual presence (f^2 = 0.543) and a medium effect on perceived enjoyment (f^2 = 0.184), highlighting its pivotal role in shaping immersive and enjoyable digital museum experiences. Perceived virtual presence, in turn, has a medium

effect on both continuance intention (f^2 = 0.151) and perceived enjoyment (f^2 = 0.296), indicating its dual influence on emotional engagement and sustained usage. Additionally, perceived enjoyment has a medium effect on continuance intention (f^2 = 0.234), underscoring the importance of hedonic experiences in promoting visitors' willingness to revisit smart

museum technologies. These findings confirm the significance of both experiential and perceptual factors in driving continued engagement in digital heritage environments.

Table 5: Effect size assessment of structural paths

Structural path	f^2
Interaction quality -> perceived enjoyment	0.184
Interaction quality -> perceived virtual presence	0.543
Perceived enjoyment -> continuance intention	0.234
Perceived virtual presence -> continuance intention	0.151
Perceived virtual presence -> perceived enjoyment	0.296

5. Discussion

The results of this research provide valuable guidance on the role of interaction quality, perceived virtual presence, and perceived enjoyment within the context of visitors' continuance intention in smart museum environments. As expected from the TAM's structure, the findings affirm that interaction quality not only has a strong direct effect on continuance intention but also indirectly affects it via perceived enjoyment and perceived virtual presence. This finding reinforces other research focused on system engagement, as responsiveness to user inputs and design centricity to users are vital to digital engagement (Shi et al., 2023; Resnick et al., 2021).

Importantly, perceived enjoyment is established as the strongest mediator, confirming its role as the leading hedonic factor within experiential contexts such as smart museums. This is consistent with earlier literature on the use of hedonic systems and gamified environments, where participants were driven to use systems based on intrinsic motives (Pereira and Tam, 2021). The strong relationship between perceived enjoyment and continuance intention ($\beta = 0.445$, $f^2 = 0.234$) indicates that, in instances when interactions are enjoyable, participants want to engage again. This reinforces the need to design interfaces that arouse curiosity, engender satisfaction, and facilitate affective bonds.

In addition, the findings highlight the role of perceived presence as both a direct predictor of continuance intention and an enjoyment antecedent. The impact of virtual presence on enjoyment ($f^2 = 0.296$) indicates that emotionally engaging experiences intensify the intent to act. This finding supports the growing body of literature that claims that users become more satisfied after being spatially and psychologically immersed in the system (Barreda-Ángeles and Hartmann, 2022). More importantly, the model shows that virtual presence also mediates the interaction quality–enjoyment relationship, which means that interface quality results in presence, which then adds value to enjoyment.

The model's strong explanatory power reinforces the value of integrating the TAM with experiential constructs of telepresence and enjoyment. This further suggests that museum curators and technology developers should center on interaction quality to enable immersive and enjoyable digital experiences. Responsiveness, clarity, and ease of use within smart spaces drastically enhance user engagement and the intention to return.

It is important to acknowledge several limitations of this study. First, despite our efforts to minimize selection bias through systematic participant selection, the convenience sampling approach may not fully represent all visitor demographics, particularly older adults who comprise only 13.8% of our sample. Second, our cross-sectional design limits causal inferences about the relationships between variables; longitudinal research would strengthen claims about continuance intention by measuring actual return behavior. Third, the findings are specific to the Chinese cultural context, potentially limiting generalizability to Western or other Asian museum environments. Future research should address these limitations through diverse sampling strategies, longitudinal designs, and cross-cultural comparative studies to validate and extend our findings across different cultural and technological contexts.

6. Conclusion

This study examined the role of perceived virtual presence and perceived enjoyment in the relationship between interaction quality and continuance intention within the context of smart museums in China. The results confirm that perceived interaction quality has a positive effect on perceived virtual presence and enjoyment, both of which enhance continuance intention. Among the perceived virtual presence and enjoyment factors, enjoyment had the most significant impact, which highlights the importance of hedonic value for postadoption activity.

The study makes a theoretical contribution by adapting the TAM to include immersive and affective factors of digital interaction with heritage resources. It also provides actionable recommendations to museum practitioners, namely, the recovery of value and repeat visitation through user-focused interaction design and immersive digital content. In the post-COVID world, museums have become more reliant on the integration of smart technologies. Understanding how to perpetually engage visitors is critical for designing impactful cultural experiences.

List of abbreviations

AI	Artificial intelligence
AR	Augmented reality
AVE	Average variance extracted
CI	Continuance intention
F^2	Effect size (f-squared statistic)
HTMT	Heterotrait–monotrait ratio
IoT	Internet of Things
IQ	Interaction quality
PE	Perceived enjoyment
PLS-SEM	Partial least squares structural equation modeling
PVP	Perceived virtual presence
rho_a	Composite reliability coefficient rho_a

rho_c	Composite reliability coefficient rho_c
SNS	Social network services
TAM	Technology acceptance model
UTAUT2	Unified theory of acceptance and use of technology 2
VR	Virtual reality

Compliance with ethical standards

Ethical considerations

Participation was entirely voluntary, and informed consent was obtained from all respondents prior to data collection. Anonymity and confidentiality were assured, and no identifying personal information was collected.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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