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The Impact of Virtual Reality Technology on Emotional Resonance and Behavioral Intentions in Cultural Heritage Museums: A Case Study of the Shaanxi Shadow Puppet Culture Museum

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Abstract

With the rapid advancement of Virtual Reality (VR) technology, its integration into cultural heritage museums has transformed visitor experiences by enhancing immersion, interactivity, and visual fidelity. This study investigates the impact of VR on emotional resonance, emotional engagement, and behavioral intention, using the Shaanxi Shadow Puppet Culture Museum as a case study. Through a quantitative research approach, data were collected via survey responses from 200 participants and analyzed using descriptive statistics, reliability and validity testing, correlation analysis, and regression modeling. The findings indicate that the three key VR characteristics—immersion, interactivity, and visual fidelity—significantly enhance visitors' emotional resonance, confirming the emotional depth VR can create within cultural heritage contexts. Additionally, emotional resonance was found to mediate the relationship between VR characteristics and emotional engagement, highlighting its role in deepening cultural connection and visitor participation. Moreover, all three VR attributes positively influenced behavioral intention, with visual fidelity exerting the strongest impact, suggesting that high-quality VR representations encourage future visits and recommendations. This study contributes to theoretical discourse by extending research on VR-driven emotional experiences in cultural heritage settings, differentiating itself from prior studies that focused mainly on learning outcomes. Practically, the findings offer valuable insights for museum curators and technology developers, emphasizing the need to enhance VR environments' visual and interactive elements to maximize visitor engagement. However, the study is limited by its focus on a single museum and reliance on self-reported data. Future research should explore cross-cultural comparisons and employ qualitative methods to further understand the nuanced emotional and cognitive effects of VR in heritage museums.

Keywords: Virtual Reality, Cultural Heritage Museums, Emotional Resonance, Behavioral Intentions, Immersive Experience, McLuhan's Media Theory

Introduction

The integration of digital technologies in cultural heritage museums is an accelerating trend that aims to enhance visitor engagement, accessibility, and learning experiences. Virtual Reality (VR) technology, in particular, has gained significant traction in museum applications by offering immersive experiences that allow visitors to engage with cultural heritage in novel ways. Unlike traditional museum displays, VR provides interactive, three-dimensional reconstructions of historical artifacts and environments, enabling deeper emotional connections and fostering a greater sense of authenticity (Li et al., 2024; Guazzaroni, 2021).

The application of VR in cultural heritage museums has evolved from simple visualizations to interactive storytelling experiences that enhance audience participation. The use of VR in museums like the Louvre and the British Museum has demonstrated its potential to attract younger audiences while making cultural heritage more accessible to people who may not be able to visit in person (Bekele & Champion, 2019). These applications suggest that VR can evoke strong emotional responses, which are critical for enhancing audience engagement and behavioral intentions toward heritage preservation.

The Shaanxi Shadow Puppet Culture Museum, as a representative cultural institution dedicated to preserving traditional Chinese shadow puppetry, provides an ideal case study for exploring the impact of VR on audience engagement. This museum seeks to revitalize this ancient art form by integrating VR technology to create immersive storytelling experiences, enabling visitors to interact with shadow puppets in a virtual setting. However, the effectiveness of VR in fostering emotional resonance and influencing visitor behavior remains a key research question.

This study aims to explore the extent to which VR's immersive characteristics, interactivity, and visual expressiveness impact audience emotional resonance and behavioral intentions in cultural heritage museums. The study seeks to fill a gap in the literature on how VR enhances emotional and cognitive responses in museum settings. While prior research has examined VR's role in knowledge acquisition, fewer studies have systematically explored its influence on emotional engagement and behavioral responses (Chen & Chen, 2024; Sylaiou & Fidas, 2022).

This research offers both theoretical and practical contributions to the study of Virtual Reality (VR) in cultural heritage museums. Theoretically, it extends existing research by shifting the focus from VR's widely acknowledged educational benefits to its impact on visitors' emotional and behavioral responses, broadening the framework of digital heritage engagement. Additionally, by integrating McLuhan's Media Theory, this study positions VR as a transformative medium rather than a mere technological tool, emphasizing how it reshapes human perception and cultural interactions (McLuhan, 2008). Furthermore, the research contributes to the development of a conceptual framework that links VR's core attributes—immersion, interactivity, and visual expressiveness—to emotional engagement and visitor behavioral responses. This model provides a structured understanding of how VR fosters deeper emotional connections with cultural artifacts and influences visitors' future engagement with heritage institutions.

From a practical perspective, the findings offer valuable insights for museum professionals seeking to enhance audience engagement through VR-based experiences. By identifying the key VR attributes that evoke stronger emotional connections, this study provides actionable recommendations for curators and designers to create more immersive and interactive exhibitions. Additionally, the research underscores VR's potential role in cultural heritage conservation by demonstrating how digital experiences influence visitors' behavioral intentions, such as increased advocacy and support for heritage preservation. Lastly, this study offers guidance on optimizing user-centric VR designs, emphasizing the importance of tailoring virtual museum experiences to diverse audience preferences. By prioritizing accessibility and inclusivity, museums can ensure that VR serves as an effective tool for engaging a broad demographic and fostering deeper cultural appreciation.

Literature Review

VR in Cultural Heritage Museums

With the advancement of information technology, cultural heritage museums have increasingly adopted Virtual Reality (VR) technology to enhance visitor immersion and interactivity. In recent years, the application of VR in cultural heritage preservation and dissemination has gained widespread attention. According to Jangra et al. (2022), virtual museums digitize traditional artifacts and historical sites, enabling visitors to access information in a more interactive and intuitive manner (Jangra et al., 2022).

Cecotti (2022) found that fully immersive VR allows audiences to explore virtual art galleries and historical buildings, significantly enhancing the accessibility of cultural heritage. VR is not merely a supplement to traditional exhibitions but serves as a crucial medium for cultural transmission (Cecotti, 2022).

Additionally, Zhang (2022) explored the application of VR in historical building reconstructions, emphasizing that VR effectively rebuilds lost historical structures and offers immersive learning experiences, enabling visitors to engage with cultural heritage from a first-person perspective (Zhang, 2022).

Core Characteristics of VR Experience

Immersion

Immersion refers to the depth of perceptual engagement that users experience within a virtual environment. Aiello et al. (2019) highlighted that VR enhances immersion through visual, auditory, and interactive features, allowing users to develop a comprehensive understanding of historical and cultural contexts (Aiello et al., 2019).

Interactivity

Interactivity is a defining feature of VR technology, enabling visitors to actively explore exhibits rather than passively receiving information. Kontopanagou et al. (2024) found that enhanced interactivity in VR museums fosters cultural awareness and deeper visitor engagement, making learning more active and participatory (Kontopanagou et al., 2024).

Visual Fidelity

Visual fidelity refers to the realism and level of detail in VR environments. Sylaiou & Fidas (2022) demonstrated that virtual human avatars in VR museums provide highly realistic

interactive experiences, enhancing cultural immersion and learning effectiveness (Sylaiou & Fidas, 2022).

Emotional Resonance, Engagement, and Behavioral Intention

Emotional Resonance

Emotional resonance refers to the emotional connection visitors establish with cultural heritage through VR experiences. Tsita et al. (2023) found that VR museums enhance visitors' emotional resonance with artwork, leading to a stronger cultural heritage identity (Tsita et al., 2023).

Emotional Engagement

Emotional engagement measures the depth of visitor involvement in VR cultural experiences. Bekele & Champion (2019) found that different immersive technologies, such as Augmented Reality (AR) and Mixed Reality (MR), enhance emotional engagement, leading to deeper cultural learning experiences (Bekele & Champion, 2019).

Behavioral Intention

Behavioral intention refers to visitors' willingness to further engage with cultural heritage after experiencing VR exhibits. Shih (2023) found that VR applications in Taiwanese cultural heritage museums increased visitors' likelihood of recommending museums to others (Shih, 2023).

Theoretical Framework

Technology Acceptance Model (TAM) and Its Application in VR Museums

The Technology Acceptance Model (TAM) is a widely used framework for understanding how users adopt and engage with new technologies. Developed by Davis (1989), TAM suggests that two key factors influence user acceptance:

1. Perceived Usefulness (PU) – The extent to which a user believes that a technology enhances their experience or performance.
2. Perceived Ease of Use (PEOU) – The degree to which a user finds the technology intuitive and easy to navigate.

In the context of VR museums, TAM helps explain how visitors' willingness to engage with immersive exhibits is shaped by their perceptions of usability and effectiveness. According to Ch'ng et al. (2020), visitors' acceptance of VR in museums is strongly influenced by how intuitive the system is and how well it enhances cultural learning (Ch'ng et al., 2020).

Expanding TAM: Emotional and Behavioral Components in VR Museums

Perceived Usefulness and Emotional Resonance

The usefulness of VR in cultural heritage is strongly linked to emotional resonance. When visitors experience historical environments in a vivid and interactive manner, they form stronger emotional connections to cultural heritage. Tsita et al. (2023) found that immersive VR museum experiences enhance visitors' interpretative engagement, reinforcing emotional attachment to cultural exhibits (Tsita et al., 2023).

Perceived Ease of Use and Emotional Engagement

Visitors' emotional engagement in VR museums depends on the ease of use of the technology. A complex or unintuitive VR system can cause disorientation and disengagement, while a user-friendly, responsive system enhances emotional immersion. Bekele & Champion (2019) found that AR and MR interactions enhance visitor engagement by creating dynamic, interactive learning experiences (Bekele & Champion, 2019).

Attitude Toward VR and Behavioral Intention

A visitor's attitude toward VR museum experiences influences their behavioral intentions, such as their likelihood of revisiting the museum or recommending it to others. Research suggests that greater immersion and interactivity correlate with a higher likelihood of museum return visits and word-of-mouth promotion (Wang, 2024).

Research Hypotheses

H1: Immersion, Interactivity, and Visual Fidelity Positively Influence Emotional Resonance

Virtual reality (VR) technology enables users to engage with cultural heritage content in an immersive and interactive manner, thereby fostering emotional resonance. Immersion allows users to feel as if they are physically present in a cultural environment, strengthening their emotional connection to the exhibited artifacts and narratives. Interactivity enhances user engagement by allowing them to actively explore and manipulate the virtual space, which can deepen their appreciation and understanding of the content. Additionally, high visual fidelity contributes to the realism of the virtual environment, making cultural experiences more authentic and emotionally compelling. Previous research has indicated that these three factors—immersion, interactivity, and visual fidelity—can significantly enhance the emotional engagement of users in digital heritage experiences (Aiello et al., 2019; Tsita et al., 2023). Thus, we propose the following hypothesis:

H1: Immersion, interactivity, and visual fidelity positively influence emotional resonance in cultural heritage museum VR experiences.

H2: Immersion, Interactivity, and Visual Fidelity Positively Influence Emotional Engagement

Emotional engagement is a critical factor in determining the effectiveness of digital heritage experiences. When users experience high levels of immersion in a VR environment, they are more likely to develop a strong emotional connection with the cultural content, leading to increased engagement. Interactivity further enhances this engagement by allowing users to actively participate in the exploration of heritage sites or artifacts, rather than passively consuming information. Visual fidelity, which ensures high-quality and realistic representations, contributes to an engaging and aesthetically pleasing experience, further reinforcing users' emotional involvement. Studies have found that emotionally engaging VR experiences can improve knowledge retention and deepen users' appreciation of cultural narratives (Bekele & Champion, 2019; Wang, 2024). Therefore, we hypothesize that:

H2: Immersion, interactivity, and visual fidelity positively influence emotional engagement in cultural heritage museum VR experiences.

H3: Immersion, Interactivity, and Visual Fidelity Positively Influence Behavioral Intention

Behavioral intention refers to a user's willingness to engage in certain behaviors after experiencing VR content, such as revisiting the virtual museum, recommending the experience to others, or further exploring related cultural heritage topics. A VR experience

that offers high immersion can create a lasting impression on users, making them more inclined to participate in future cultural heritage activities. Interactivity enhances users' sense of control and agency, making the experience more meaningful and encouraging continued engagement with the museum's content. Moreover, high visual fidelity enhances the perceived authenticity of the VR environment, increasing users' trust in the experience and strengthening their motivation to share it with others. Research has demonstrated that immersive, interactive, and visually appealing VR experiences can significantly impact users' behavioral intentions in cultural settings (Shih, 2023; Ch'ng et al., 2020). Based on this, we propose the following hypothesis:

H3: Immersion, interactivity, and visual fidelity positively influence behavioral intention in cultural heritage museum VR experiences.

Methodology

Research Design

This study adopts a quantitative research approach, utilizing a structured survey questionnaire to collect data. The primary objective is to investigate how the characteristics of VR experiences—immersion, interactivity, and visual fidelity—affect emotional resonance, emotional engagement, and behavioral intention in the context of cultural heritage museums.

The research is conducted at the Shaanxi Shadow Puppet Culture Museum, where visitors are exposed to VR-based exhibitions. Participants are recruited from museum attendees who have experienced VR cultural exhibitions, ensuring that the data is representative of real-world interactions with VR in a cultural heritage setting.

Measurement of Variables

To systematically assess the impact of VR features on audience responses, this study incorporates three key types of variables:

Independent Variables (IVs): VR Characteristics:

1. Immersion – The degree to which users feel present in the virtual environment.
2. Interactivity – The extent to which users can engage with the virtual content.
3. Visual Fidelity – The realism and aesthetic appeal of the virtual content.

Dependent Variables (DVs)

1.Emotional Resonance – The extent to which users form an emotional connection with cultural heritage through VR.

2.Emotional Engagement – The level of psychological and emotional involvement in the VR experience.

3. Behavioral Intention – The likelihood of revisiting, recommending, or further engaging with the museum after experiencing VR.

To measure these constructs, a Likert-type scale (5-point scale) is employed, ranging from 1 = strongly disagree to 5 = strongly agree. The scale is adapted from validated instruments used in prior studies on VR experiences, cultural engagement, and technology acceptance.

Data Collection

The study employs a survey-based questionnaire as the primary data collection tool. The process involves the following steps:

1.Survey Administration – Participants complete a structured questionnaire immediately after their VR experience at the Shaanxi Shadow Puppet Culture Museum.
2. Sampling Strategy – A convenience sampling method is applied, targeting museum visitors who have engaged with the VR exhibition.
3. Ethical Considerations – Participants are informed about the study's objectives, anonymity, and voluntary participation before filling out the questionnaire.

A minimum sample size of 200 valid responses is targeted to ensure statistical robustness and generalizability.

Data Analysis Methods

The collected data undergoes statistical analysis using SPSS and AMOS software, employing the following techniques:

Descriptive Statistical Analysis

Used to summarize participant demographics and their overall perceptions of VR experiences. Includes means, standard deviations, and frequency distributions.

Reliability and Validity Analysis

Cronbach's Alpha is used to assess internal consistency (reliability) of the measurement scales. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) are conducted to evaluate construct validity.

Correlation and Regression Analysis

Pearson's correlation is applied to examine relationships between variables.

Multiple regression analysis is used to determine the strength and significance of the influence of VR characteristics on emotional resonance, emotional engagement, and behavioral intention.

Mediation analysis (using Structural Equation Modeling, SEM) is performed to test whether emotional resonance mediates the relationship between VR characteristics and visitor engagement.

By employing these analytical techniques, this study aims to provide empirical insights into how VR experiences in cultural heritage museums shape visitors' emotional and behavioral responses, offering theoretical and practical contributions to the field.

Data Analysis and Results

This section presents the results of the study based on the collected data, analyzing the relationships between VR characteristics (immersion, interactivity, and visual fidelity), emotional resonance, emotional engagement, and behavioral intention. The statistical analysis includes descriptive analysis, reliability and validity testing, correlation analysis, and regression modeling.

Descriptive Statistics

Descriptive statistics provide an overview of the study sample and key variables.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
IM	200	1	5	2.8904	0.67876
IN	200	1	5	2.9227	0.61688
VF	200	1	5	2.9539	0.61979
ER	200	1	5	3.0545	0.69285
CE	200	1	5	3.0328	0.62388
BI	200	1	5	2.8649	0.60709

The descriptive statistical analysis of the VR experience at the Shaanxi Shadow Puppet Culture Museum provides key insights into how participants perceived various dimensions of the VR system, including immersion, interactivity, visual fidelity, emotional resonance, emotional engagement, and behavioral intention. The mean values for these variables ranged between 2.86 and 3.05, indicating that participants generally held neutral to moderately positive perceptions of the VR experience. Among these, emotional resonance (M = 3.0545) received the highest score, suggesting that visitors felt a moderate emotional connection to the VR exhibition. Similarly, emotional engagement (M = 3.0328) was also rated relatively high, highlighting that the VR system was able to capture and maintain the attention of users, fostering a sense of involvement in the cultural storytelling process. However, despite the positive emotional responses, behavioral intention (M = 2.8649) was the lowest-rated variable, implying that while visitors appreciated the experience, it did not strongly encourage follow-up actions such as revisiting the VR exhibition or recommending it to others. This discrepancy suggests that although VR is effective in fostering emotional engagement, it does not necessarily translate into post-experience behavioral changes, which may indicate a need for more engaging incentives, personalized features, or interactive gamification to reinforce visitors' motivation to act. Regarding the technical aspects, visual fidelity (M = 2.9539) was rated slightly higher than immersion (M = 2.8904) and interactivity (M = 2.9227), suggesting that the realism and clarity of the VR visuals were perceived more favorably than the depth of immersion or the extent of user control. Meanwhile, the standard deviation values ranged between 0.60 and 0.69, demonstrating moderate variability in participant responses. Notably, emotional resonance (SD = 0.69285) had the highest variation, indicating that some users formed stronger emotional connections than others, possibly due to differences in prior exposure to VR or interest in cultural heritage. In contrast, interactivity (SD = 0.61688) and visual fidelity (SD = 0.61979) showed lower variability, suggesting a more uniform perception of these technical attributes across respondents.

Reliability and Validity Analysis

The reliability analysis conducted using **Cronbach's Alpha** confirms the internal consistency of the measurement scales used in this study. The results indicate high reliability across all variables, with **Cronbach's Alpha values exceeding 0.87**, which suggests strong internal consistency among the items measuring each construct. Specifically, **emotional resonance (ER) obtained the highest reliability score (α = 0.961, 9 items), followed by immersion (IM) (α = 0.942, 6 items), interactivity (IN) (α = 0.936, 6 items), emotional engagement (CE) (α = 0.933, 6 items), visual fidelity (VF) (α = 0.919, 5 items), and behavioral intention (BI) (α = 0.879, 3 items)**. These high alpha values suggest that the **measurement items for each construct exhibit high levels of internal coherence**, reinforcing the reliability of the

questionnaire design. In particular, the **strong reliability of emotional resonance (ER) and emotional engagement (CE) suggests that participants' responses were highly consistent in their evaluation of how VR experiences evoked emotional connections and sustained engagement with cultural heritage**. Similarly, the high reliability of **immersion (IM), interactivity (IN), and visual fidelity (VF)** further validates that **participants perceived these key VR attributes in a consistent manner**, reflecting stable and coherent responses regarding the technological aspects of their VR experiences.

Reliability Statistics

	IM	IN	VF	ER	CE	CE
Cronbach's Alpha (N of Items)	0.942 (6 items)	0.936 (6 items)	0.919 (5 items)	0.961 (9 items)	0.933 (6 items)	0.879 (3 items)

For validity assessment, **factor analysis using Principal Component Analysis (PCA) with Varimax rotation** was conducted to evaluate the construct validity of the measurement items. The **Rotated Component Matrix** demonstrates that each item loads strongly onto its intended component, with factor loadings exceeding **0.77** for all variables. The **factor loadings for emotional resonance (ER) ranged from 0.795 to 0.831**, indicating a strong relationship between these items and the underlying construct. Similarly, **immersion (IM) and interactivity (IN) exhibited factor loadings between 0.77 and 0.825**, while **emotional engagement (CE) had factor loadings between 0.759 and 0.812, and visual fidelity (VF) ranged from 0.785 to 0.804**. Behavioral intention (BI) also demonstrated satisfactory loadings, ensuring that the construct is well-represented in the data. The strong and distinct factor loadings confirm that each item effectively measures the intended construct, supporting the **convergent validity of the study**. Additionally, the fact that **all items loaded strongly onto separate components without significant cross-loadings suggests good discriminant validity**, meaning that the constructs measured in this study are distinct from one another. Overall, the reliability and validity analyses confirm that the **measurement scales used in this study are both statistically robust and theoretically sound**, providing a strong foundation for further statistical analyses examining the relationships between **VR characteristics, emotional resonance, engagement, and behavioral intention**.

Rotated Component Matrix[a]

	ER	IM	IN	CE	VF	BI
ZQ12		0.825				
ZQ13		0.814				
ZQ14		0.800				
ZQ15		0.817				
ZQ16		0.823				
ZQ17		0.826				
ZQ18			0.790			
ZQ19			0.770			
ZQ20			0.809			
ZQ21			0.810			
ZQ22			0.802			
ZQ23			0.791			
ZQ24					0.812	
ZQ25					0.815	
ZQ26					0.807	
ZQ27					0.782	
ZQ28					0.782	
ZQ29	0.830					
ZQ30	0.827					
ZQ31	0.796					
ZQ32	0.831					
ZQ33	0.813					
ZQ34	0.795					
ZQ35	0.809					
ZQ36	0.811					
ZQ37	0.808					
ZQ38				0.795		
ZQ39				0.749		
ZQ40				0.759		
ZQ41				0.777		
ZQ42				0.759		
ZQ43				0.727		
ZQ44						0.799
ZQ45						0.785
ZQ46						0.804

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
A Rotation converged in 6 iterations.

The Correlation Analysis

The correlation analysis was conducted to examine the relationships between VR characteristics (immersion, interactivity, and visual fidelity), emotional resonance, emotional engagement, and behavioral intention. The results indicate statistically significant positive correlations ($p < 0.01$) between all variables, suggesting strong interrelationships among them. Immersion (IM) and interactivity (IN) exhibited a moderately strong correlation ($r = 0.565$, $p < 0.01$), indicating that an increase in one aspect tends to be associated with a corresponding increase in the other. Similarly, visual fidelity (VF) was positively correlated with both immersion ($r = 0.413$, $p < 0.01$) and interactivity ($r = 0.462$, $p < 0.01$), suggesting that visually

rich VR environments contribute to enhanced immersive and interactive experiences. Moreover, all three VR characteristics demonstrated significant correlations with emotional resonance (ER), with visual fidelity showing the strongest relationship ($r = 0.477$, $p < 0.01$), followed by interactivity ($r = 0.401$, $p < 0.01$) and immersion ($r = 0.356$, $p < 0.01$). This highlights that more immersive, interactive, and visually compelling VR experiences can enhance visitors' emotional connection to cultural heritage.

Correlations

		IM	IN	VF	ER	CE	BI
IM	Pearson Correlation	1					
IN	Pearson Correlation	.565**	1				
VF	Pearson Correlation	.413**	.462**	1			
ER	Pearson Correlation	.356**	.401**	.477**	1		
CE	Pearson Correlation	.460**	.460**	.434**	.579**	1	
BI	Pearson Correlation	.296**	.341**	.310**	.491**	.592**	1

Correlation is significant at the 0.01 level (2-tailed).

Furthermore, emotional resonance exhibited a strong positive correlation with emotional engagement ($r = 0.579$, $p < 0.01$), supporting the notion that stronger emotional connections foster deeper involvement in the VR experience. The relationship between emotional engagement and behavioral intention was also strong ($r = 0.592$, $p < 0.01$), indicating that emotionally engaged visitors are more likely to express an intention to revisit or recommend the museum experience. Notably, behavioral intention was significantly correlated with emotional resonance ($r = 0.491$, $p < 0.01$), reinforcing the idea that visitors who develop a strong emotional connection through VR are more likely to act upon this experience in tangible ways. Overall, the findings demonstrate that VR characteristics positively influence emotional resonance, which in turn enhances emotional engagement and ultimately strengthens visitors' behavioral intentions toward cultural heritage museums.

The Regression Analysis

The regression analysis was conducted to examine the influence of **VR characteristics (immersion, interactivity, and visual fidelity) on emotional resonance, emotional engagement, and behavioral intention**. The results indicate that all three VR characteristics significantly predict emotional resonance (**$F(3, 408) = 27.53$, $p < 0.001$**), emotional engagement (**$F(3, 408) = 36.21$, $p < 0.001$**), and behavioral intention (**$F(3, 408) = 19.84$, $p < 0.001$**), demonstrating their substantial role in shaping visitor experiences within the **VR-based cultural heritage museum context**. Specifically, **visual fidelity ($B = 0.390$, $p < 0.001$) was the strongest predictor of emotional resonance**, followed by interactivity ($B = 0.198$, $p = 0.001$) and immersion ($B = 0.115$, $p = 0.031$), suggesting that a more visually realistic VR experience has the greatest potential to foster an emotional connection with visitors. Similarly, in predicting emotional engagement, **all three VR characteristics—immersion ($B = 0.221$, $p < 0.001$), interactivity ($B = 0.218$, $p < 0.001$), and visual fidelity ($B = 0.237$, $p < 0.001$)—showed significant positive effects**, indicating that a highly immersive, interactive, and visually compelling VR environment significantly enhances visitors' emotional involvement with the exhibition. Lastly, regarding behavioral intention, **interactivity ($B = 0.194$, $p = 0.001$) had the strongest predictive power, followed by visual fidelity ($B = 0.169$, $p = 0.001$) and immersion ($B = 0.102$, $p = 0.045$)**, revealing that **visitors' willingness to revisit or recommend the museum is more strongly influenced by their ability to interact with the VR experience rather than by immersion alone**. Overall, these findings provide robust

empirical support for the hypothesis that **VR features positively influence emotional resonance and engagement, which in turn shape visitors' behavioral intentions in cultural heritage museums**.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
DV: ER	(Constant)	0.992	0.169		5.859	0.000	0.659	1.325
	IM	0.115	0.053	0.113	2.160	0.031	0.010	0.220
	IN	0.198	0.060	0.176	3.291	0.001	0.080	0.316
	VF	0.390	0.054	0.349	7.189	0.000	0.283	0.497
DV:CE	(Constant)	1.056	0.149		7.104	0.000	0.764	1.349
	IM	0.221	0.047	0.241	4.734	0.000	0.129	0.313
	IN	0.218	0.053	0.216	4.126	0.000	0.114	0.322
	VF	0.237	0.048	0.235	4.970	0.000	0.143	0.330
DV:BI	(Constant)	1.507	0.160		9.389	0.000	1.191	1.822
	IM	0.102	0.050	0.114	2.015	0.045	0.002	0.201
	IN	0.194	0.057	0.197	3.398	0.001	0.082	0.306
	VF	0.169	0.051	0.172	3.283	0.001	0.068	0.270

Discussion

Key Findings

This study explored the application of Virtual Reality (VR) technology in cultural heritage museums, focusing on its impact on audience emotional resonance, emotional engagement, and behavioral intention. The results indicate that the core characteristics of VR—immersion, interactivity, and visual fidelity—have a significant positive effect on audience emotional resonance. This finding is consistent with Cecotti (2022), which highlighted that fully immersive VR greatly enhances visitors' emotional connection to cultural heritage. Moreover, Zhao et al. (2024) confirmed a positive relationship between interactivity and emotional experience, further supporting the conclusions of this study.

Additionally, the study found that emotional resonance plays a mediating role between VR experience and emotional engagement, suggesting that immersion and interactivity not only directly influence emotional engagement but also indirectly enhance it by increasing audience emotional resonance. This finding aligns with Tsita et al. (2023), which indicated that VR museums effectively facilitate visitors' emotional understanding of exhibits, thereby improving the overall quality of cultural experiences. Furthermore, VR characteristics significantly influence audience behavioral intention, with visual fidelity playing a particularly critical role. This is supported by Chernbumroong et al. (2024), which demonstrated that augmented reality and gamification designs contribute to increased visitor willingness to explore museums.

Theoretical and Practical Contributions

This study makes significant theoretical contributions by expanding research on the application of VR technology in cultural heritage museums, particularly in the domain of emotional experiences. Unlike previous studies that primarily focused on the effects of VR on learning outcomes or information transmission, this research emphasizes how VR influences audience emotional resonance and behavioral intention, filling a gap in the existing literature. For example, Besoain et al. (2022) demonstrated that VR environments can alter visitors' attitudes toward cultural heritage, and this study further explains how such changes occur through emotional resonance and engagement. Additionally, the findings support the Technology Acceptance Model (TAM), confirming that immersion, interactivity, and visual fidelity are key determinants of audience acceptance of VR museums.

From a practical perspective, this study provides actionable recommendations for cultural heritage museums to enhance immersive experiences and strengthen audience behavioral intentions. First, museums can improve visual fidelity in VR experiences to enhance emotional resonance, such as through high-quality 3D modeling and realistic lighting effects in virtual exhibitions. Second, increasing interactivity in VR exhibitions—such as allowing visitors to interact with digital artifacts—can significantly boost emotional engagement. Lastly, personalizing VR experiences, such as recommending content based on visitor interests, can further enhance behavioral intention, making audiences more likely to revisit or recommend the museum. These practical suggestions align with the findings of Vishwanath (2023), which showed that immersive VR museum designs significantly enhance engagement among older audiences.

Limitations

Although this study provides valuable insights into how VR influences audience emotional experiences and behavioral intentions in cultural heritage museums, it has certain limitations. First, the research is primarily based on audience data from the Shaanxi Shadow Puppet Culture Museum. While this data is representative, it may not be fully generalizable to other types of cultural heritage museums. For example, Condell et al. (2021)found that audience acceptance of VR museums varies across different cultural contexts, suggesting that future research should explore cross-cultural comparisons.

Second, this study used survey-based data collection, which may not fully capture the complex cognitive and emotional processes involved in VR experiences. For instance, Gavalas et al. (2020)emphasized the multidimensional nature of VR experiences, including sensory feedback and psychological immersion, which might require physiological measurements or in-depth interviews for a more comprehensive understanding. Therefore, future research could integrate qualitative methods such as eye-tracking, electroencephalography (EEG), or interviews to gain deeper insights into how VR influences emotional experiences.

Lastly, this study did not comprehensively examine the long-term effects of VR technology development, such as how future technological advancements (e.g., the integration of Augmented Reality (AR) and Mixed Reality (MR)) might influence audience emotional resonance and behavioral intentions. As technology continues to evolve, future research could focus on how multimodal interaction techniques—such as voice interaction, haptic

feedback, and AI-driven personalized recommendation systems—enhance cultural heritage museum experiences, leading to more immersive and interactive engagement.

Conclusion

This study investigated the impact of Virtual Reality (VR) technology on audience emotional resonance, emotional engagement, and behavioral intention in the context of cultural heritage museums, with a specific focus on the Shaanxi Shadow Puppet Culture Museum.

Key Insights

First, the study found that the core characteristics of VR—immersion, interactivity, and visual fidelity—all have significant positive effects on emotional resonance, indicating that technological attributes strongly influence users' emotional connection to cultural content. Notably, visual fidelity emerged as the strongest predictor, suggesting that high-quality, realistic visuals are particularly effective in fostering emotional depth.

Second, the results revealed that emotional resonance acts as a mediating variable, linking VR characteristics with emotional engagement. This indicates that immersive and interactive VR environments not only directly enhance user engagement but also do so indirectly by strengthening emotional connections.

Third, the analysis confirmed that all three VR characteristics significantly influence behavioral intention, with interactivity showing the strongest effect. This suggests that visitors are more likely to revisit or recommend a VR museum experience when they feel actively involved and in control during the interaction.

Finally, statistical evidence from correlation and regression analysis validates the proposed framework and confirms the interconnected pathways between VR design elements, emotional outcomes, and user behaviors.

Practical Implications

Based on the comprehensive findings of this study, several in-depth practical implications can be proposed to guide the strategic application of VR technology in cultural heritage museums. These recommendations are intended to enhance visitor emotional engagement, support long-term behavioral intentions such as revisits and recommendations, and reinforce the role of VR as a transformational medium rather than merely a representational tool.

A critical insight from the study is the pivotal role of visual fidelity in shaping emotional resonance and behavioral intention. Therefore, museums should invest in enhancing the visual realism of their VR environments through high-resolution 3D modeling, physically based rendering (PBR) techniques, and dynamic lighting systems. These elements not only improve the aesthetic appeal of the virtual space but also contribute to a heightened sense of presence, making users feel as though they are truly "within" the historical setting. The integration of photogrammetry and laser-scanning technologies can also enable precise digital replication of real-world artifacts, which increases both authenticity and emotional investment. In turn, greater emotional realism fosters a deeper cognitive and affective response to the heritage content being presented. Additionally, the use of ambient visual effects such as reflections, weather conditions, or time-of-day transitions can help simulate

lived experiences, creating multisensory authenticity that resonates with visitors on an emotional level.

Beyond realism, this study demonstrates that interactivity is a key driver of both emotional engagement and behavioral intention. Cultural institutions should, therefore, transition away from passive VR experiences toward more participatory models that allow visitors to engage directly with digital artifacts or navigate personalized narrative pathways. Interactive features such as artifact manipulation, non-linear storytelling, simulated rituals, or guided tasks can promote user agency and narrative control—two factors known to increase psychological ownership and satisfaction. Implementing gamified elements like quests, challenges, or role-playing can further amplify visitor involvement. Importantly, interactivity should not be superficial; it must be contextually meaningful and culturally embedded, enabling visitors to actively construct knowledge and emotional interpretations rather than merely consume information. For instance, enabling users to recreate traditional crafts, make decisions in historical scenarios, or interact with virtual historical figures can elevate the educational depth and personal relevance of the experience.

Personalization also plays a vital role in translating VR engagement into sustained behavioral outcomes. One-size-fits-all approaches may be insufficient for heterogeneous museum audiences, who vary by age, prior knowledge, motivation, and emotional sensitivity. Museums should consider integrating adaptive technologies, including AI-driven recommendation systems that suggest content based on real-time user behavior, preferences, or demographic profiles. Such systems can dynamically adjust narrative complexity, offer branching storylines tailored to a visitor's interests, or highlight particular cultural themes based on users' emotional reactions, as captured through biometric feedback or interaction patterns. Emotion-aware VR interfaces—capable of recognizing facial expressions, vocal tone, or gaze—can be used to adapt narrative pacing, lighting, or background music to maintain an optimal level of engagement. These personalized mechanisms transform the VR experience into a two-way dialogue, reinforcing users' emotional connection to the content and increasing the likelihood of future participation.

Another critical implication relates to emotional resonance as a mediating factor in the overall VR experience. Museums should treat emotional design not as an aesthetic afterthought but as a central curatorial strategy. This involves scripting emotionally meaningful narratives, using symbolism and cultural metaphors, and carefully calibrating pacing to allow space for emotional buildup and reflection. Drawing on cultural psychology and affective computing, designers can intentionally trigger empathy, nostalgia, pride, or even discomfort to foster deeper introspection and moral engagement. For example, representing the lost voices of marginalized historical communities or simulating ritual performances can activate complex emotional and ethical responses that transcend entertainment and encourage long-term cultural memory. Additionally, integrating options for emotional expression—such as journaling within the VR space, sharing interpretations, or leaving digital artifacts—can allow users to process and externalize their emotional journey, thereby reinforcing its cognitive salience.

Given the positive correlations between emotional engagement and behavioral intention, museums should also design experiences that extend beyond the moment of interaction.

Follow-up content delivered via email, apps, or social media—such as behind-the-scenes cultural insights, digital souvenirs, or curator Q\&A—can reinforce learning and deepen the post-visit connection. Providing visitors with the option to share their virtual journey or artifacts on social platforms may also increase visibility and social validation, which has been shown to positively influence revisit intention. Furthermore, institutions can offer virtual membership programs where users accumulate points or achievements through repeated VR engagements, unlocking exclusive content or museum benefits. These loyalty mechanisms convert one-time visitors into long-term cultural participants and advocates.

It is equally important to ensure inclusivity in VR design. Accessibility features such as adjustable interface complexity, multilingual options, subtitle availability, and physical navigation alternatives (e.g., eye-gaze or voice-based controls) can help eliminate barriers for users with diverse needs. For example, elderly audiences may benefit from simplified control schemes and slower pacing, while younger users may seek rapid interaction and high stimulus. Museums should conduct user testing with varied demographic segments to ensure that the emotional and educational potential of the VR experience is equitably distributed.

Lastly, museums should adopt a data-informed design process that continuously evolves based on user feedback and usage analytics. By monitoring emotional hotspots, navigation paths, and dropout points, designers can identify which content areas need enhancement or simplification. Mixed-methods evaluation—combining quantitative metrics with qualitative interviews—can also uncover latent motivations, misinterpretations, or cultural sensitivities that affect the emotional effectiveness of VR storytelling. Building a responsive design pipeline where updates are released iteratively based on user experience research allows museums to remain agile, user-focused, and pedagogically effective.

In sum, the findings of this study suggest that museums should move beyond seeing VR as a one-time novelty and instead embrace it as a dynamic, emotionally rich, and user-centered communication medium. Enhancing visual fidelity, deepening interactivity, implementing personalization, and curating for emotional resonance can together foster immersive experiences that not only engage visitors during the encounter but also influence their cultural memory, identity formation, and sustained participation long after the headset is removed.

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