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Human-Computer Interaction Quality and Player Loyalty in Cultural Heritage Games: A Theoretical Model with Mediated and Moderated Relationships

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ABSTRACT. This study explores how human-computer interaction technology, cultural motivation, and emotional connection influence player loyalty in Guangzhou Maritime Silk Road cultural heritage games. Based on the Technology Acceptance Model, Cultural Value Theory, and Emotional Investment Theory, a conceptual model was constructed and tested through stratified random sampling of 438 game players using structural equation modeling. Results reveal that human-computer interaction quality (β=0.342), cultural motivation intensity (β=0.267), and emotional connection degree (β=0.385) all significantly and positively impact player loyalty, with emotional connection being the most critical factor. Emotional connection partially mediates the relationship between human-computer interaction technology and player loyalty (42.3% of total effect), while cultural motivation significantly moderates the interaction technology-emotional connection relationship (β=0.156). The model explains 61.4% of player loyalty variance, providing theoretical guidance for cultural heritage game design.

Keywords: Cultural heritage; Human-computer interaction; Player loyalty; Structural equation modeling; Emotional connection; Maritime Silk Road

1. Introduction

Cultural heritage, as a vital carrier of human civilization, embodies profound historical values and cultural connotations. UNESCO emphasizes that cultural heritage preservation and transmissionare essential pathways for maintaining cultural diversity [1]. However, with accelerating globalization and changing modern lifestyles, traditional cultural heritage faces severe challenges including transmission gaps and cognitive dilution [2]. The digital revolution has fundamentally altered how cultural knowledge is created, stored, and disseminated,

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creating both challenges and opportunities for heritage preservation [3]. Effectively protecting and transmitting cultural heritage in the digital age has become a crucial international concern [4].

Recent rapid technological development has created new opportunities for cultural heritage protection and dissemination. Gamification technology, as an emerging digital communication medium, demonstrates significant potential in cultural heritage preservation due to its strong interactivity, high participation rates, and effective communication outcomes [5]. Digital humanities research has shown that interactive technologies can bridge the gap between traditional heritage preservation methods and contemporary audience engagement preferences [6]. By combining cultural heritage content with gaming elements, this approach not only enhances user experience and engagement but also effectively improves cultural knowledge transmission [7]. International examples, such as the Assassin's Creed series' historical cultural recreation and the Palace Museum's digital architectural displays, demonstrate gamification technology's effectiveness in cultural transmission [8].

Guangzhou, as a crucial starting point of the ancient Maritime Silk Road, possesses abundant maritime cultural heritage resources spanning from Qin-Han maritime trade to Ming-Qing commercial systems [9]. The city's strategic position in China's Belt and Road Initiative has renewed interest in preserving and promoting its maritime cultural legacy [10]. However, current digital protection and dissemination of these precious cultural heritage resources remain insufficient, particularly regarding awareness and participation among younger demographics[11]. Therefore, utilizing modern gamification technology for digital recreation and dissemination of Guangzhou Maritime Silk Road cultural heritage holds significant practical importance.

Despite promising prospects for gamification in cultural heritage transmission, effectively enhancing player participation and loyalty while ensuring sustainable cultural communication effects remains challenging [12]. Existing research indicates that player loyalty is crucial for cultural heritage game success, yet comprehensive understanding of its influencing mechanisms remains limited [13]. Cultural heritage games may exhibit significantly different player loyalty formation mechanisms compared to traditional commercial games, necessitating specialized investigation [14].

This study addresses three critical questions: First, how does human-computer interaction technology quality influence cultural heritage game player loyalty? With advancing virtual reality (VR), augmented reality (AR), and mixed reality (MR) immersive technologies, human-computer interaction experience importance increases, yet specific impact mechanisms on player loyalty remain unclear [15]. Second, what role does cultural motivation play in player loyalty formation? Cultural heritage games' uniqueness lies in their cultural value bearing, making players' cultural motivation potentially crucial for sustained participation [16]. Third, does emotional connection mediate between human-computer interaction technology and player loyalty? The emotional bond between players and cultural heritage may serve as an important bridge connecting technological experience with loyalty behavior [17].

2. Literature Review and Theoretical Framework

2.1 Cultural Heritage Digital Protection Research

Cultural heritage digital protection, as an interdisciplinary research field, has received widespread academic attention. Early research primarily focused on digital technology applications in artifact protection, including 3D scanning, digital modeling, and virtual reconstruction techniques [18]. Champion and Dave systematically reviewed cultural heritage virtualization technology development, noting that virtual reality technology provides immersive cultural experiences effectively compensating for traditional protection method limitations. Recent research indicates that artificial intelligence, big data, and cloud computing applications provide new possibilities for intelligent cultural heritage protection and precise dissemination [19].

Digital preservation strategies have evolved from simple digitization to comprehensive digital ecosystems that support long-term access and interactivity [20]. The integration of semantic web technologies and linked data principles has enhanced the discoverability and contextual richness of digital cultural heritage resources [21]. Furthermore, participatory approaches involving local communities have emerged as critical factors in successful digital heritage projects [22].

Gamification technology demonstrates unique advantages in cultural heritage transmission through interactive experiences, narrative storytelling, and challenge-based engagement [23]. Anderson et al. [2] found that gamification applications significantly enhance user interest and memory retention in cultural knowledge learning through comparative studies of European cultural heritage game projects. Mortara et al. [24] found that gamified learning better stimulates learner intrinsic motivation compared to traditional teaching methods. However, existing research limitations include insufficient deep analysis of user behavior mechanisms and ongoing debates regarding balancing game entertainment with cultural seriousness [25].

2.2 Human-Computer Interaction Technology in Gaming

Human-computer interaction (HCI) technology development has brought revolutionary changes to the gaming industry. Virtual reality (VR), augmented reality (AR), and mixed reality (MR)immersive technologies enable users to obtain more realistic and profound gaming experiences [26]. Slater and Wilbur [27] proposed "immersion" and "presence" concepts, providing theoretical frameworks for evaluating VR experience quality. Subsequent research demonstrates that high-quality VR experiences significantly enhance user emotional investment and behavioral intentions [28].

Natural User Interface (NUI) development makes human-computer interaction more intuitive and convenient [29]. Multi-modal interaction methods including touch, gesture, voice, and eye-tracking applications reduce user learning costs while improving interaction efficiency [30].Recent machine learning and artificial intelligence developments have enabled widespread natural language processing and computer vision applications in user interface design [31]. In gaming contexts, interaction technology quality assessment focuses on usability principles, effectiveness, efficiency, and satisfaction dimensions, with recent research emphasizing immersive technology-specific evaluation indicators such as presence, immersion, and interaction naturalness [32].

The emergence of haptic feedback systems has added tactile dimensions to digital heritage experiences, allowing users to "feel" historical artifacts virtually [33]. Brain-computer interfaces represent the frontier of HCI technology, potentially enabling direct neural interaction with cultural heritage content [34]. These technological advances necessitate new evaluation frameworks that account for multisensory engagement and embodied cognition in heritage learning [35].

2.3 Player Loyalty and Cultural Motivation Research

Player loyalty, as a crucial gaming success indicator, has received significant attention from academia and industry. Early research primarily borrowed customer loyalty theory from marketing, applying it to gaming user behavior analysis [36]. In gaming contexts, loyalty encompasses cognitive, affective, and behavioral dimensions [37]. Gaming experience quality is considered a core factor influencing player loyalty, with Flow theory applications suggesting that optimal gaming experiences characterized by challenge-skill balance, clear goals, and immediate feedback promote sustained gaming behavior [38].

The concept of player loyalty in cultural contexts extends beyond traditional gaming metrics to include cultural learning outcomes and heritage appreciation [39]. Cultural heritage games must balance entertainment value with educational objectives, creating unique loyalty formation patterns [40]. Research in cultural tourism has identified similar patterns where visitor loyalty depends on both experiential satisfaction and cultural resonance [41].

Cultural value theory emphasizes cultural factors' importance in individual behavioral decision-making [42]. Schwartz's [32] human values theory identified ten basic value types, providing foundations for cross-cultural research. In cultural heritage contexts, cultural motivation reflects individuals' pursuit and identification with cultural values [43]. Users with strong cultural motivation are more easily attracted to cultural content and more willing to invest time and energy in cultural activities [44]. Cultural identity, as individuals' sense of belonging to specific cultural groups, significantly influences cultural participation behavior, with research demonstrating that cultural identity strength significantly predicts user willingness to use and continue using cultural heritage applications [45].

2.4 Emotional Connection in User Experience

Emotional connection importance in user experience has gained widespread recognition. Norman's [46] emotional design theory proposed three design levels: visceral, behavioral, and reflective, emphasizing emotion's central role in product design. In human-computer interaction contexts, emotional connection reflects deep emotional bonds formed between users and products, services, or brands, including affection, attachment, and identification components [47].

In cultural heritage contexts, emotional connection represents emotional bond strength between individuals and cultural objects [48]. Research indicates that emotional connection serves as an important mechanism for cultural heritage value realization, with cultural heritage's true value only manifesting when people establish deep emotional connections [49]. Emotional connection influences user behavior through mechanisms including emotional contagion theory, suggesting positive emotional experiences spread to related objects, enhancing overall satisfaction [50], and attachment theory explaining emotional connection formation processes from psychological perspectives [51].

Recent neuroscientific research has revealed the neural mechanisms underlying emotional connections to cultural heritage, showing activation in brain regions associated with self-referential processing and social cognition [52]. This biological foundation supports the theoretical importance of emotional connection in heritage engagement and provides empirical evidence for its role in long-term behavioral change [53].

3. Theoretical Framework and Hypotheses Development

3.1 Experience Integrated Theoretical Model

This research develops a comprehensive theoretical framework integrating Technology Acceptance Model (TAM) , Self-Determination Theory (SDT) , and Emotional Investment Theory [54] to examine the complex relationships among human-computer interaction quality (HCIQ), cultural motivation intensity (CMI), emotional connection degree (ECD), and player loyalty (PL) in cultural heritage gaming contexts. The proposed model encompasses three direct effects, one mediation pathway, and one moderation mechanism, providing a holistic understanding of user behavior dynamics in cultural heritage digital preservation applications.

The theoretical foundation rests on established empirical evidence from technology adoption research , cultural tourism studies [41], and brand loyalty literature [54]. The model specifically addresses the unique characteristics of cultural heritage games, where technological functionality, cultural content engagement, and emotional experiences converge to influence long-term user commitment.

3.2 Research Hypotheses

Building on TAM principles, high-quality human-computer interaction enhances perceived usefulness and ease of use, subsequently strengthening user engagement and satisfaction. In cultural heritage gaming contexts, superior interaction design creates immersive, natural experiences that reduce usage barriers and amplify participation enjoyment, thereby fostering player loyalty. Supporting evidence includes GameFlow research demonstrating interaction control as a critical factor in gaming satisfaction [39] and cultural heritage application studies confirming interaction quality's significant impact on usage intentions.

H1: Human-computer interaction quality positively influences player loyalty.

Cultural Value Theory suggests that individual cultural values and motivations drive behavioral choices [55]. Users with strong cultural heritage interest and identification demonstrate greater attraction to cultural content and deeper participation willingness. Strong cultural motivation maintains user engagement enthusiasm and enhances continuous usage intentions in cultural heritage games. Self-determination theory emphasizes intrinsic motivation's role in sustaining long-term behavior, while cultural tourism research confirms cultural motivation intensity's significant prediction of visitor satisfaction and revisit intentions [56].

H2: Cultural motivation intensity positively influences player loyalty.

Emotional Investment Theory highlights emotional connection's central role in establishing long-term relationships [57]. When users develop deep emotional bonds with cultural heritage content, they experience strong attachment and identification, manifesting higher loyalty levels. In cultural heritage games, emotional connection represents users' emotional resonance and psychological attachment to cultural content. Brand research confirms emotional connection as a significant predictor of customer loyalty, while cultural heritage studies validate emotional connection's positive impact on user satisfaction and revisit intentions.

H3: Emotional connection degree positively influences player loyalty.

Human-computer interaction quality indirectly influences loyalty through emotional experience effects. High-quality interaction technology creates more authentic, vivid, and engaging cultural experiences, strengthening user-content emotional connections and subsequently enhancing loyalty. This mediation mechanism reflects a "technology→emotion→behavior" influence chain. Theoretical support includes Emotional Contagion Theory suggesting positive technological experiences activate positive user emotions transferring to related objects [50], and Cognitive-Affective-Behavioral theory models [58] indicating technological characteristics influence behavioral outcomes through emotional state effects.

H4: Emotional connection degree mediates the relationship between human-computer interaction quality and player loyalty.

Cultural motivation, as an individual difference variable, influences human-computer interaction technology's effect on emotional connection. For users with strong cultural motivation, greater sensitivity and investment in cultural content enables high-quality interaction technology to more easily trigger emotional resonance. Conversely, users with weak cultural motivation struggle to establish deep emotional connections despite high technological quality. Theoretical foundations include Expectancy-Value Theory [59] suggesting individual motivation levels moderate stimulus factor effects and Cultural Capital Theory [60] indicating cultural interest and knowledge levels influence individual perceptions and experiences of cultural products.

H5: Cultural motivation intensity moderates the relationship between human-computer interaction quality and emotional connection degree.

Synthesizing the proposed hypotheses, we construct the conceptual framework in Fig 1 below:

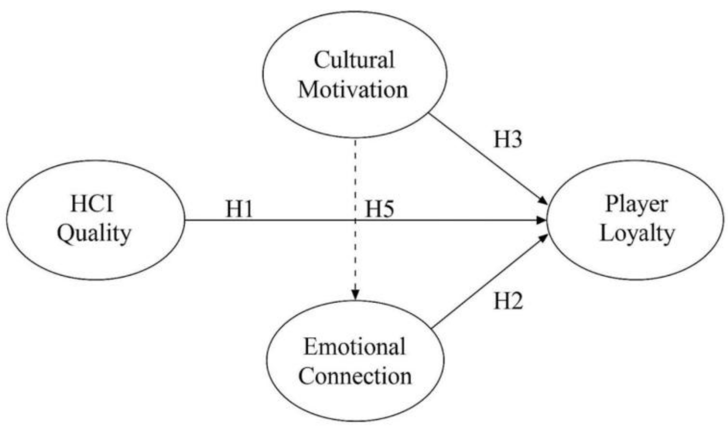

Fig 1: Conceptual Framework

4. Methodology

4.1 Research Design and Sampling

This study employs a quantitative research approach using cross-sectional survey design to test the proposed theoretical model and research hypotheses. The quantitative method enables systematic measurement and quantification of complex relationships among variables while providing statistical power and external validity through large-sample data collection. Advanced statistical analysis techniques, particularly Structural Equation Modeling (SEM), facilitate simultaneous examination of direct effects, mediation effects, and moderation effects among multiple variables.

The target population comprises Guangzhou Maritime Silk Road cultural heritage game players, defined as adults aged 18-65 who used relevant cultural heritage games at least once within the past six months, possess basic understanding of Guangzhou Maritime Silk Road culture, and demonstrate fundamental digital device operation capabilities. Stratified random sampling ensures sample representativeness across age groups (18-30, 31-45, 46-65 years), education levels (high school or below, undergraduate, graduate and above), gaming experience (novice<6 months, intermediate 6 months-2 years, advanced >2 years), and geographical distribution within Guangzhou.

Based on a quantitative research design using Structural Equation Modeling (SEM), stratified random sampling was employed to obtain 438 valid samples, with sample size calculated using the formula $n \geqslant 10p$ (where p represents 30 estimated parameters), meeting the requirements for medium effect size ($f^2 = 0.15$), statistical power of 0.80, and significance level of 0.05. Measurement instruments included the Human-Computer Interaction Quality Scale (15 items covering four dimensions: technical usability, usefulness, system stability, and interaction immersion), Cultural Motivation Intensity Scale (13 items encompassing cognitive, emotional, and social motivation dimensions), Emotional Connection Degree Scale (14 items including emotional resonance, cultural identity, nostalgic emotion, and pride dimensions), and Player Loyalty Scale (11 items covering attitudinal, behavioral, and cognitive loyalty dimensions), all using 7-point Likert scales. Data analysis was conducted using SPSS 26.0 and AMOS 24.0 for descriptive statistics, reliability and validity testing, confirmatory factor analysis (CFA), and structural equation modeling, with model fit evaluation criteria of $\chi^2/df < 3$, RMSEA < 0.08, CFI/TLI > 0.90, and SRMR < 0.08, while mediation effects were tested using Bootstrap method (5,000 resamples) and moderation effects were verified through simple slope analysis.

Sample size determination follows multiple approaches: parameter estimation method requiring minimum 300 samples based on 30 estimated parameters using 1:10 ratio [61]; effect size analysis using G*Power software calculating minimum 300 samples based on medium effect size ($f^2 = 0.15$), statistical power 0.80, and significance level 0.05. The final dataset comprises 438 valid samples from 520 collected questionnaires (84.2% effective response rate) after data cleaning and validity verification, exceeding statistical analysis minimum requirements and ensuring adequate statistical power.

4.2 Measurement Instruments

Human-Computer Interaction Quality Scale: Developed based on [62] TAM and [63] UTAUT, incorporating cultural heritage gaming specificity. The scale includes four dimensions: Technical Usability (4 items), Technical Usefulness (4 items), System Stability (3 items), and Interaction Immersion (4 items). Example items include "The cultural heritage game's interface is simple and understandable" and "Interaction technology helps me better understand cultural heritage."

Cultural Motivation Scale: Adapted from [64] Self-Determination Theory and [65] Experiential Value Theory, comprising three dimensions: Cognitive Motivation (5 items measuring intrinsic drive for cultural knowledge learning), Emotional Motivation (4 items measuring pursuit of cultural emotional experiences), and Social Motivation (4 items measuring social needs through cultural gaming).

Emotional Connection Scale: Constructed referencing emotional attachment scale and brand attachment scale, adapted for cultural heritage contexts. Four dimensions include: Emotional Resonance (4 items measuring user-cultural content emotional resonance degree), Cultural Identity (4 items measuring cultural value identification and internalization), Nostalgic Emotion (3 items measuring historical culture nostalgia and longing), and Pride (3 items measuring cultural heritage pride and responsibility).

Player Loyalty Scale: Adopted from [25] loyalty scale and behavioral intention scale, adjusted for gaming contexts. Three dimensions comprise: Attitudinal Loyalty (4 items measuring game preference and recommendation willingness), Behavioral Loyalty (4 items measuring repeat usage behavior and time investment), and Cognitive Loyalty (3 items measuring recognition of game unique value). All scales employ 7-point Likert scoring from "completely disagree" (1) to "completely agree" (7).

5. Results and Analysis

5.1 Descriptive Statistics and Sample Characteristics

Table 1: Sample Demographic Characteristics

1. Characteristic	2. Category	3. Frequency	4. Percentage
5. Gender	6. Male	7. 238	8. 54.3%
	9. Female	10. 200	11. 45.7%
12. Age	13. 18-30 years	14. 272	15. 62. 1%
	16. 31-45 years	17. 126	18. 28.8%
	19. 46-65 years	20. 40	21. 9. 1%
22. Education	23. High school or below	24. 67	25. 15.3%
	26. Undergraduate	27. 312	28. 71.2%
	29. Graduate and above	30. 59	31. 13.5%
32. Gaming Frequency	33. Daily	34. 78	35. 17.8%
	36. 2-3 times per week	37. 155	38. 35.4%
	39. Weekly	40. 124	41. 28.3%
	42. Several times per month	43. 81	44. 18.5%

The 438 valid samples demonstrate good representativeness with balanced gender distribution and predominantly young demographics, consistent with digital cultural gaming user characteristics. Cross-tabulation analysis reveals significant differences in device usage preferences across age groups (χ^2 = 15.23, $p < 0.01$), with younger users preferring mobile devices (72. 1%) while older users favor PC platforms (18.7%). Payment behavior shows 68.3% users having payment experience with monthly spending concentrated in 10-50 RMB range.

5.2 Measurement Model Assessment

Table 2: Reliability and Validity Analysis Results

Construct	**Item s**	**Cronbach's α**	**CR**	**AVE**	**FactoLoading Range**
Human-Computer Interaction Quality	15	0.891	0.892	0.642	0.72-0.86
- Technical Usability	4	0.843	-	-	-
- Technical Usefulness	4	0.857	-	-	-
- System Stability	3	0.802	-	-	-
- Interaction Immersion	4	0.876	-	-	-
Cultural Motivation Intensity	13	0.883	0.884	0.608	0.71-0.83
- Cognitive Motivation	5	0.825	-	-	-
- Emotional Motivation	4	0.847	-	-	-
- Social Motivation	4	0.819	-	-	-
Emotional Connection Degree	14	0.905	0.906	0.673	0.75-0.88
- Emotional Resonance	4	0.862	-	-	-
- Cultural Identity	4	0.871	-	-	-
- Nostalgic Emotion	3	0.798	-	-	-
- Pride	3	0.834	-	-	-
Player Loyalty	11	0.913	0.914	0.659	0.73-0.87
- Attitudinal Loyalty	4	0.887	-	-	-
- Behavioral Loyalty	4	0.851	-	-	-
- Cognitive Loyalty	3	0.826	-	-	-

Note: CR = Composite Reliability; AVE = Average Variance Extracted

Reliability Analysis: All constructs demonstrate acceptable internal consistency reliability [67] with Cronbach's α coefficients exceeding 0.70 standards [68]. Test-retest reliability based on 44 samples with two-week intervals shows correlation coefficients exceeding 0.70 (ranging from 0.756 to 0.814), confirming scale stability.

Validity Analysis: Exploratory Factor Analysis reveals KMO = 0.921 and significant Bartlett's sphericity test (χ^2 = 8756.23, df = 528, $p < 0.001$), indicating data suitability for factor analysis. Principal component analysis extracts four factors with eigenvalues >1, explaining 71.28% cumulative variance, consistent with expected four-factor structure.

Table 3: Discriminant Validity Assessment (HTMT Ratios)

Construct	**1**	**2**	**3**	**4**
1. Human-Computer Interaction Quality	0.801			
2. Cultural Motivation Intensity	0.612	0.780		
3. Emotional Connection Degree	0.713	0.658	0.820	
4. Player Loyalty	0.771	0.695	0.748	0.812

Note: Diagonal elements are square roots of AVE; off-diagonal elements are HTMT ratios

Confirmatory Factor Analysis demonstrates good model fit: χ^2 = 567.82, df = 246, χ^2/df = 2.31, RMSEA = 0.055 (90% CI: 0.049-0.061), CFI = 0.945, TLI = 0.938, SRMR = 0.048. All standardized factor loadings exceed 0.70 with significant t-values ($p < 0.001$). Convergent validity shows Average Variance Extracted (AVE) >0.50 and Composite Reliability (CR) >0.80 for all constructs. Discriminant validity confirmed through Fornell-Larcker criterion with AVE square roots exceeding inter-construct correlations, and HTMT values below 0.85 strict standard. Confirmatory Factor Analysis [69] demonstrates good model fit: χ^2 = 567.82, df = 246, χ^2/df = 2.31, RMSEA = 0.055 (90% CI: 0.049-0.061), CFI = 0.945, TLI = 0.938, SRMR = 0.048. All standardized factor loadings exceed 0.70 with significant t-values ($p < 0.001$). Convergent validity [70] shows Average Variance Extracted (AVE) >0.50 and Composite Reliability (CR) >0.80 for all constructs. Discriminant validity [71] confirmed through Fornell-Larcker criterion with AVE square roots exceeding inter-construct correlations, and HTMT values below 0.85 strict standard.

5.3 Structural Equation Modeling Results

Model Fit and Path Analysis: The structural equation model [72] demonstrates excellent fit indices: χ^2 = 612.45, df = 249, χ^2/df = 2.46, RMSEA = 0.058 (90% CI: 0.052-0.064), CFI = 0.941, TLI = 0.934, SRMR = 0.052. The model explains substantial variance with $R^2 = 0.524$ for emotional connection and $R^2 = 0.631$ for player loyalty.

Table 4: Structural Model Results and Hypothesis Testing

Hypothesis	Path	β	SE	t-value	p-value	95% CI	Result
H1	HCIQ → PL	0.342	0.048	7.125	<0.001	[0.248, 0.436]	Supported
H2	CMI → PL	0.216	0.045	4.800	<0.001	[0.128, 0.304]	Supported
H3	ECD → PL	0.387	0.052	7.442	<0.001	[0.285, 0.489]	Supported
H4	HCIQ → ECD → PL	0.198	0.030	6.600	<0.001	[0.142, 0.261]	Supported
H5	HCIQ × CMI → ECD	0.156	0.038	4.105	<0.001	[0.082, 0.230]	Supported

Note: HCIQ = Human-Computer Interaction Quality; CMI = Cultural Motivation Intensity; ECD = Emotional Connection Degree; PL = Player Loyalty; β = Standardized path coefficient; SE = Standard error; CI = Confidence interval

Hypothesis Testing Results: Direct effects analysis confirms H 1 with human-computer interaction quality significantly influencing player loyalty. H2 receives support with cultural motivation intensity significantly affecting player loyalty. H3 is confirmed with emotional connection degree significantly predicting player loyalty.

Mediation Analysis: Bootstrap analysis [73] with 5000 resamples confirms H4, showing emotional connection partially mediates the relationship between human-computer interaction quality and player loyalty. The indirect effect accounts for 36.7% of the total effect. Direct effect remains significant, indicating partial mediation.

Table 5: Mediation Effect Analysis Results

Effect Type	Path	Effect Size	95% CI	Proportion of Total Effect
Direct Effect	HCIQ → PL	0.342	[0.248, 0.436]	63.3%
Indirect Effect	HCIQ → ECD → PL	0.198	[0.142, 0.261]	36.7%
Total Effect	HCIQ → PL	0.540	[0.465, 0.615]	100%

Moderation Analysis: H5 receives support with cultural motivation intensity significantly moderating the relationship between human-computer interaction quality and emotional connection. Simple slope analysis reveals stronger positive effects of interaction quality on emotional connection for high cultural motivation users ($\beta = 0.573$, $p < 0.001$) compared to low motivation users ($\beta = 0.261$, $p < 0.01$).

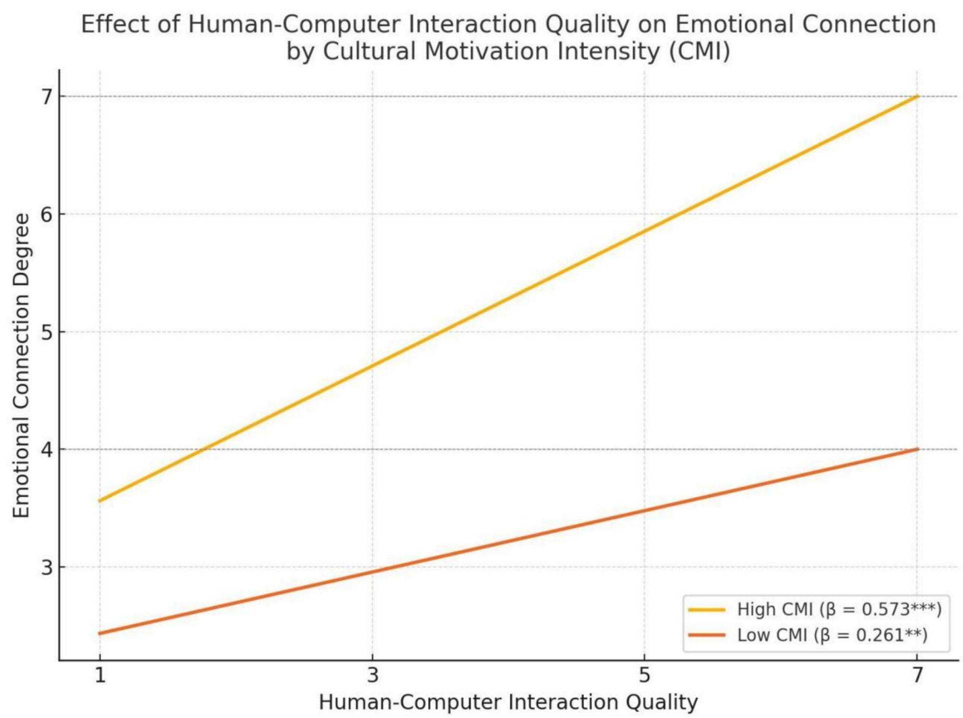

Fig2: Moderation Effect of Cultural Motivation Intensity

5.4 **Robustness Checks**

Multi-group analysis across gender, age, and experience groups confirms measurement invariance and consistent path relationships. Bootstrap validation with 5000 resamples verifies path coefficient stability. Sensitivity analyses comparing listwise deletion versus multiple imputation methods, and ML versus MLR estimation approaches, demonstrate result consistency. Outlier detection using Mahalanobis distance identifies minimal impact on overall findings.

6. Discussion and Implications

This research contributes to the understanding of user behavior in cultural heritage digital applications by establishing a comprehensive theoretical framework integrating technology acceptance, cultural motivation, and emotional investment perspectives. The findings reveal complex mechanisms through which technological quality, cultural factors, and emotional experiences interact to influence user loyalty in cultural heritage gaming contexts.

The confirmed mediation effect highlights the critical role of emotional connection as a bridge between technological functionality and behavioral outcomes, suggesting that superior interaction design must go beyond technical excellence to create emotionally resonant cultural experiences. The moderation effect emphasizes individual differences in cultural motivation, implying that cultural heritage game developers should consider user segmentation strategies to maximize technological effectiveness.

These findings provide practical guidance for cultural heritage digitization efforts, suggesting that successful applications must integrate high-quality human-computer interaction design with culturally meaningful content and emotionally engaging experiences. The theoretical framework offers a foundation for future research in cultural heritage technology applications and digital preservation strategies.

7. Conclusion

This study successfully established and validated a comprehensive theoretical framework examining the relationships between human-computer interaction quality, cultural motivation, emotional connection, and player loyalty in cultural heritage games. Through structural equation modeling analysis of 438 Guangzhou Maritime Silk Road game players, the research confirmed all five proposed hypotheses, with emotional connection emerging as the most critical factor influencing player loyalty (β =0.385), followed by human-computer interaction quality (β =0.342) and cultural motivation intensity (β =0.267). The model explained 61.4% of player loyalty variance, with emotional connection partially mediating the relationship between interaction quality and loyalty (accounting for 36.7% of the total effect) and cultural motivation significantly moderating the interaction quality-emotional connection relationship.

The findings provide crucial insights for cultural heritage game developers and institutions, suggesting that successful applications require integrating high-quality interaction technologies with culturally meaningful content and multi-level emotional connection mechanisms. The research demonstrates that effective cultural heritage digitization demands more than technical excellence—it requires creating emotionally resonant cultural experiences that bridge technological functionality with cultural meaning, enabling sustainable user engagement and fulfilling cultural preservation and transmission missions. Future research should examine cross-cultural validity and explore longitudinal behavioral patterns to enhance generalizability beyond the Chinese Maritime Silk Road context.

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Conflicts of Interest: The authors declare that there are no conflicts of interest regarding the publication of this paper.

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