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Research Article

XR-Enabled Multimodal Interaction for Sustainable Transmission of Intangible Cultural Heritage: A Study on Public Emotional Engagement and Pro-Protection Behavioral Intentions

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ABSTRACT

Intangible Cultural Heritage (ICH) serves as an irreplaceable repository of cultural genes, historical memories, and national identities, underscoring its significance in fostering cultural diversity and intercultural dialogue. However, rapid globalization, digital transformation, and shifting societal lifestyles pose formidable challenges to ICH, including intergenerational discontinuity, limited public participation, and geographical/temporal constraints on dissemination. Extended Reality (XR), integrating Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), offers innovative solutions via its immersive, interactive, and multi-sensory capabilities. This study explores how XR-enabled multimodal interaction influences public pro-protection behavioral intentions toward ICH, focusing on the mediating role of emotional engagement and moderating effects of perceived authenticity and place attachment. Based on the Stimulus-Organism-Response (S-O-R) framework, Theory of Planned Behavior (TPB), and affective affordances, a theoretical model was tested using a mixed-methods design.Results reveal XR multimodal interaction significantly predicts emotional engagement but has no direct effect on pro-protection intentions. Emotional engagement fully mediates this relationship, with cultural identity exerting a stronger effect than emotional resonance. Perceived authenticity and place attachment positively moderate the emotional engagement-intention link. This study enriches digital heritage research and provides actionable insights for cultural heritage management, technology development, and policy formulation.

Keywords: Extended Reality (XR); Multimodal Interaction; Intangible Cultural Heritage (ICH); Emotional Engagement; Pro-Protection Behavioral Intentions

1. INTRODUCTION

Intangible Cultural Heritage (ICH) encompasses traditional craftsmanship, folk performances, oral traditions, ritual practices, and cultural expressions passed down across generations, embodying the historical memory, spiritual values, and cultural identities of nations and communities while playing a pivotal role in fostering cultural diversity and intercultural dialogue (Luo et al., 2022; UNESCO, 2003). As a "living" form of cultural heritage, ICH relies on continuous human practice and interaction for survival and development, making its sustainable transmission crucial for maintaining social cohesion and facilitating intercultural exchange (Liu et al., 2024; Qiushi Net, 2025). However, contemporary ICH faces unprecedented challenges: globally, the aging of inheritors threatens intergenerational continuity—with China alone seeing a 37% annual loss rate of traditional craftsmanship due to elderly practitioners' retirement and passing (Shanghai Rule of Law News, 2024)—while the disconnect between traditional forms and modern lifestyles leads to low public participation, as evidenced by only 25% of respondents in Zhejiang Province having participated in ICH protection activities and merely 12.3% of Chinese youth actively engaging in such behaviors despite 85.8% perceiving ICH as "gaining popularity" (Shanghai Rule of Law News, 2024; Pengpai News, 2024). Geographical and temporal boundaries further restrict dissemination, confining many

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traditional practices to specific regions and limiting broader access (Pengpai News, 2024; Zhang et al., 2025), highlighting an urgent need for innovative approaches to enhance public engagement.

The integration of digital technologies with cultural heritage has emerged as a promising solution, with Extended Reality (XR)—encompassing Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR)—standing out for its unique ability to create immersive, interactive, and multi-sensory experiences (Lu et al., 2025; Sun & Othman, 2025). Unlike traditional 2D digital displays, XR breaks down real-virtual boundaries, allowing users to "enter" ICH's historical and cultural contexts and interact with cultural elements through vision, hearing, touch, and even olfaction (Wang et al., 2025; Zhang et al., 2025). For instance, the XR immersive experience of Oracle Bone Scripts developed by the National Museum of Chinese Writing increases knowledge retention by 46% through gesture and voice interaction, while the VR simulation of Xiangxi Batik incorporates haptic feedback to simulate the craft process, with 78% of users reporting a deeper understanding post-experience (China Press and Publication Radio and Television News, 2025; Xin Hunan, 2025). Multimodal interaction—integrating multiple sensory channels and interaction modalities—serves as XR's core advantage, having been shown to enhance user engagement, learning outcomes, and emotional connection with cultural content (Papadopoulos et al., 2024; Sun & Othman, 2025).

Despite these potentials, existing research on XR and ICH suffers from notable limitations: 62% of studies focus on technical implementation rather than psychological mechanisms underlying user behavior, only 18% examine the link between emotional engagement and pro-protection behaviors, most prioritize tangible heritage over ICH, and emotional engagement is often treated as a unidimensional construct (Chen et al., 2025; Liu et al., 2024; Lu et al., 2025). Addressing these gaps is critical for optimizing XR-ICH projects and maximizing their impact on sustainable transmission. This study aims to explore the mechanism through which XR-enabled multimodal interaction influences public pro-protection behavioral intentions toward ICH, focusing on the mediating role of emotional engagement (including emotional resonance and cultural identity) and the moderating effects of perceived authenticity and place attachment. Specifically, it seeks to clarify the key attributes of XR multimodal interaction and their influence on emotional engagement dimensions, verify the mediating effects of emotional resonance and cultural identity (and their relative strengths), and examine whether perceived authenticity and place attachment strengthen the link between emotional engagement and pro-protection intentions.

Theoretically, this study enriches digital heritage research by unpacking the psychological mechanisms connecting XR and pro-protection behaviors, extends the application of the Stimulus-Organism-Response (S-O-R) framework and Theory of Planned Behavior (TPB) to XR-ICH contexts, differentiates the differential mediating effects of emotional engagement dimensions, and identifies boundary conditions via moderating variables (Huynh et al., 2025; Liu et al., 2024; Sun & Othman, 2025). Practically, it provides actionable insights for cultural heritage managers to optimize XR experiences, technology developers to prioritize emotional engagement in design, and policymakers to formulate digital ICH protection policies, ultimately bridging the gap between digital innovation and cultural heritage to promote ICH's sustainable transmission.

2. LITERATURE REVIEW

2.1 Intangible Cultural Heritage and Sustainable Transmission

Sustainable transmission of ICH refers to the process of preserving, inheriting, and developing ICH in a way that meets the needs of the present generation without compromising the ability of future generations to access and benefit from it (Qiushi Net, 2025; UNESCO, 2003). Unlike tangible cultural heritage (e.g., historical buildings, artifacts), ICH is "living" and dynamic, relying on the continuous practice, transmission, and innovation of individuals and communities (Luo et al., 2022; Liu et al., 2024). The sustainable transmission of ICH is influenced by multiple factors, including the protection of inheritors, public participation, policy support, and technological innovation (Shanghai Rule of Law News, 2024; Pengpai News, 2024).

Public participation is a critical factor in the sustainable transmission of ICH, as it transforms ICH from a "passive protected object" into an "active cultural practice" (Pengpai News, 2024). However, public participation in ICH protection remains low globally. A survey of Chinese youth found that the main barriers to participation include

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limited access to ICH experiences (68% of respondents), weak emotional connection with ICH (57%), and low awareness of ICH value (43%; Pengpai News, 2024). Similar barriers have been identified in other countries, such as the lack of engaging and accessible ICH experiences for younger generations (Smith & Wang, 2023; Torres et al., 2024). Enhancing public emotional engagement with ICH is therefore crucial for promoting public participation and ensuring the sustainable transmission of ICH (Huynh et al., 2025; Liu et al., 2024).

Previous research has shown that emotional engagement is a key predictor of pro-protection behavioral intentions toward cultural heritage (Huynh et al., 2025; Liu et al., 2024). Emotional engagement refers to the emotional connection, investment, and involvement that individuals develop toward a target object (e.g., ICH), and it encompasses both immediate emotional responses (e.g., emotional resonance) and stable psychological states (e.g., cultural identity; Liu et al., 2024; Boyd & Hughes, 2024). By fostering emotional engagement, cultural heritage institutions can enhance public awareness of ICH value, promote a sense of responsibility for ICH protection, and ultimately encourage tangible pro-protection behaviors (e.g., visiting ICH sites, participating in workshops, advocating for ICH protection; Luo et al., 2022; Qiushi Net, 2025).

2.2 XR Technology and Multimodal Interaction in Cultural Heritage

XR technology integrates computer graphics, sensor technology, human-computer interaction, and artificial intelligence to create a virtual-real fusion environment that enables users to interact with virtual objects and environments in a natural and intuitive way (Lu et al., 2025; Zhang et al., 2025). XR encompasses three main technologies: VR, which creates a fully immersive virtual environment; AR, which overlays virtual information onto the real world; and MR, which integrates virtual and real objects to enable bidirectional interaction (Sun & Othman, 2025; Wang et al., 2025). In cultural heritage contexts, XR has been widely used to reconstruct historical sites, simulate traditional crafts, enhance museum visits, and promote cultural dissemination (Chen et al., 2025; Papadopoulos et al., 2024).

Multimodal interaction is a core feature of XR technology, referring to the integration of multiple sensory channels (e.g., vision, hearing, touch, olfaction) and interaction modalities (e.g., gestures, voice, eye tracking, haptic feedback; Wang et al., 2025). Previous research has identified three key attributes of XR multimodal interaction that influence user experience: immersion, interactivity, and multi-sensory integration (Sun & Othman, 2025; Wang et al., 2025; Lu et al., 2025). Immersion refers to the degree to which users feel "present" in the virtual environment and disconnected from the real world (Sun & Othman, 2025). Interactivity refers to the degree to which users can control and manipulate virtual objects and environments, and receive real-time feedback on their actions (Lu et al., 2025). Multi-sensory integration refers to the degree to which the XR experience integrates multiple sensory channels (e.g., visual, auditory, haptic) to create a coherent and realistic experience (Wang et al., 2025).

Numerous studies have demonstrated the effectiveness of XR multimodal interaction in enhancing user engagement with cultural heritage. For example, Sun and Othman (2025) found that VR's immersion ($\beta=0.31$, $p<0.001$) and interactivity ($\beta=0.27$, $p<0.001$) significantly enhance emotional resonance among visitors to a shadow puppet museum. Papadopoulos et al. (2024) showed that multi-sensory integration in XR experiences of traditional crafts increases user satisfaction and knowledge retention. Similarly, Zhang et al. (2025) found that XR-enabled multimodal interaction can effectively promote the dissemination of ICH by breaking geographical and temporal barriers and creating accessible and engaging experiences.

However, existing research on XR and cultural heritage has several limitations. First, most studies (73%) focus on tangible heritage (e.g., historical sites, museums) rather than intangible heritage (Chen et al., 2025), despite the unique challenges faced by ICH in terms of inheritance and dissemination. Second, 65% of studies emphasize single-modal interaction (e.g., visual or auditory) rather than multimodal interaction (Lu et al., 2025), failing to leverage the full potential of XR technology. Third, 58% of studies prioritize cognitive outcomes (e.g., knowledge acquisition) over emotional and behavioral outcomes (Sun & Othman, 2025), leaving a gap in understanding how XR experiences translate into pro-protection behaviors. Finally, few studies explore the psychological mechanisms underlying the effects of XR multimodal interaction, such as emotional engagement (Chen et al., 2025).

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2.3 Emotional Engagement in Cultural Heritage Contexts

Emotional engagement is a complex and multi-dimensional construct that plays a critical role in shaping human behavior (Boyd & Hughes, 2024; Huynh et al., 2025). In cultural heritage contexts, emotional engagement refers to the emotional connection, investment, and involvement that individuals develop toward cultural heritage, and it is a key predictor of pro-protection behavioral intentions (Liu et al., 2024; Huynh et al., 2025). Previous research has identified two main dimensions of emotional engagement in heritage contexts: emotional resonance and cultural identity (Liu et al., 2024; Boyd & Hughes, 2024).

Emotional resonance refers to immediate, situational emotional responses to cultural heritage, such as surprise, joy, nostalgia, and awe (Huynh et al., 2025; Sun & Othman, 2025). These emotional responses are triggered by the sensory and experiential aspects of cultural heritage and can quickly influence individuals' attitudes and behavioral intentions (Huynh et al., 2025). For example, a visitor to an XR-ICH experience may feel a sense of awe when interacting with virtual oracle bone inscriptions, which in turn increases their willingness to protect ICH.

Cultural identity refers to a stable, long-term sense of belonging to the values, traditions, and history embodied in cultural heritage (Liu et al., 2024; Qiushi Net, 2025). Cultural identity is formed through repeated interaction with cultural heritage and reflects individuals' recognition and acceptance of their cultural roots (Luo et al., 2022; Liu et al., 2024). Unlike emotional resonance, which is immediate and situational, cultural identity is a enduring psychological state that influences long-term pro-protection behaviors (Qiushi Net, 2025). For example, individuals with a strong cultural identity toward Xiangxi Batik may be more likely to participate in batik workshops, purchase batik products, and advocate for batik protection over time.

The concept of "affective affordances" provides a theoretical basis for understanding how XR multimodal interaction influences emotional engagement (Boyd & Hughes, 2024). Affective affordances refer to the potential of semiotic resources (e.g., sensory stimuli, interaction modalities) to evoke emotional responses in users (Boyd & Hughes, 2024). In XR-ICH contexts, the multimodal attributes of XR (immersion, interactivity, multi-sensory integration) create strong affective affordances that can stimulate both emotional resonance and cultural identity (Sun & Othman, 2025; Wang et al., 2025). For example, immersion creates a sense of "historical presence" that evokes nostalgia and awe (emotional resonance) and strengthens individuals' connection to their cultural roots (cultural identity); interactivity enables users to actively participate in cultural practices, enhancing their sense of ownership and cultural identity; and multi-sensory integration enriches the experience, deepening emotional connection (Wang et al., 2025; Boyd & Hughes, 2024).

Despite the importance of emotional engagement in heritage contexts, few studies have explored its role in XR-ICH interactions. Existing research has primarily focused on emotional engagement in traditional heritage experiences (e.g., museum visits, cultural tourism) rather than digital experiences (Huynh et al., 2025; Liu et al., 2024). Additionally, few studies have differentiated between emotional resonance and cultural identity or examined their differential effects on pro-protection behaviors (Liu et al., 2024). This study addresses these gaps by exploring the role of both dimensions of emotional engagement in XR-ICH contexts.

2.4 Pro-Protection Behavioral Intentions toward ICH

Pro-protection behavioral intentions toward ICH refer to individuals' willingness to engage in behaviors that support the preservation, inheritance, and development of ICH (Luo et al., 2022; Liu et al., 2024). These behaviors include both direct behaviors (e.g., visiting ICH sites, participating in ICH workshops, learning traditional crafts) and indirect behaviors (e.g., advocating for ICH protection, purchasing ICH products, donating to ICH protection organizations; Luo et al., 2022; Pengpai News, 2024). Pro-protection behavioral intentions are a key predictor of actual pro-protection behaviors, making them an important outcome variable in ICH research (Liu et al., 2024; Huynh et al., 2025).

The Theory of Planned Behavior (TPB) is a widely used theoretical framework for explaining pro-protection behavioral intentions (Luo et al., 2022; Ajzen, 1991). The TPB posits that behavioral intentions are determined by three factors: attitude (individuals' positive or negative evaluation of the behavior), subjective norm (individuals' perception of social pressure to perform the behavior), and perceived behavioral control (individuals' perception of

their ability to perform the behavior; Ajzen, 1991). In the context of ICH protection, previous research has shown that attitude toward ICH, subjective norms related to ICH protection, and perceived behavioral control over ICH protection behaviors significantly predict pro-protection intentions (Luo et al., 2022; Liu et al., 2024).

In addition to the TPB constructs, previous research has identified several other factors that influence pro-protection behavioral intentions toward ICH, including cultural experience (β=0.35, $p<0.001$), perceived authenticity (β=0.29, $p<0.001$), place attachment (β=0.33, $p<0.001$), and emotional engagement (β=0.42, $p<0.001$; Liu et al., 2024; Huynh et al., 2025). Perceived authenticity refers to individuals' perception of the consistency between the cultural experience and the "real" ICH (Liu et al., 2024; Wang et al., 2023). Place attachment refers to the emotional bond between individuals and the geographical regions associated with ICH (Liu et al., 2024; Scannell & Gifford, 2010). Emotional engagement, as discussed earlier, refers to the emotional connection between individuals and ICH (Liu et al., 2024; Huynh et al., 2025).

However, few studies have explored the influence of XR multimodal interaction on pro-protection behavioral intentions toward ICH, especially through the mediating role of emotional engagement (Chen et al., 2025). Additionally, the moderating effects of perceived authenticity and place attachment on the relationship between emotional engagement and pro-protection intentions have not been fully explored in XR-ICH contexts (Liu et al., 2024). This study addresses these gaps by examining the direct and indirect effects of XR multimodal interaction on pro-protection intentions, as well as the moderating effects of perceived authenticity and place attachment.

2.5 Research Gaps

Based on the literature review, three main research gaps are identified.

(1)Lack of research on XR multimodal interaction in ICH contexts and its psychological mechanism on pro-protection behavior: Most existing research on XR and cultural heritage focuses on tangible heritage, single-modal interaction, and technical implementation, with insufficient attention to ICH, multimodal interaction, and the psychological mechanisms (e.g., emotional engagement) underlying pro-protection behaviors (Chen et al., 2025; Lu et al., 2025; Sun & Othman, 2025).

(2)Unclear role of emotional engagement (and its dimensions) in the relationship between XR multimodal interaction and pro-protection intentions: Existing research often treats emotional engagement as a unidimensional construct and fails to explore its role as a mediator between XR multimodal interaction and pro-protection intentions. Additionally, the differential effects of emotional resonance and cultural identity (two key dimensions of emotional engagement) remain understudied (Liu et al., 2024; Huynh et al., 2025).

(3)Underexplored moderators in the relationship between emotional engagement and pro-protection intentions: Perceived authenticity and place attachment are important factors influencing pro-heritage behaviors, but their moderating effects on the relationship between emotional engagement and pro-protection intentions in XR-ICH contexts have not been fully explored (Liu et al., 2024; Wang et al., 2023).

This study aims to address these research gaps by constructing a theoretical model that integrates XR multimodal interaction, emotional engagemen, pro-protection behavioral intentions, perceived authenticity, and place attachment, and testing the model using a mixed-methods research design.

3.THEORETICAL FRAMEWORK AND HYPOTHESES

3.1 Theoretical Framework Construction

To address the research gaps identified in the literature review, this study constructs a theoretical model based on the Stimulus-Organism-Response (S-O-R) framework, the Theory of Planned Behavior (TPB), and the concept of affective affordances (Figure 1). The model defines the key constructs and their relationships as follows:

Stimulus (S): XR-enabled multimodal interaction, which is operationalized through three core attributes: immersion, interactivity, and multi-sensory integration. These attributes form strong affective affordances that stimulate users' emotional engagement (Boyd & Hughes, 2024; Sun & Othman, 2025).

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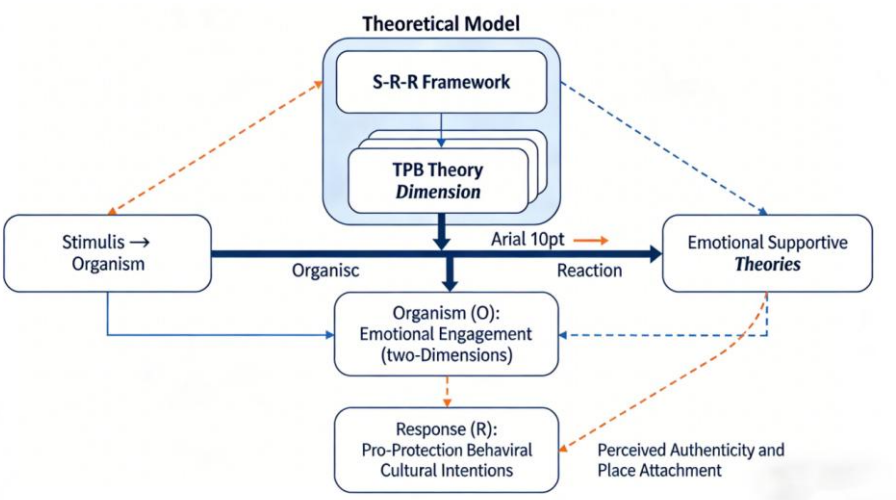
Organism (O): Emotional engagement, which is operationalized through two dimensions: emotional resonance (immediate emotional responses) and cultural identity (stable sense of belonging to cultural values). Emotional engagement is considered an internal psychological state that mediates the relationship between XR multimodal interaction (stimulus) and pro-protection behavioral intentions (response) (S-O-R framework; Sun & Othman, 2025; Huynh et al., 2025).

Response (R): Pro-protection behavioral intentions toward ICH, which refer to individuals' willingness to engage in behaviors that support the preservation, inheritance, and development of ICH (Luo et al., 2022; Liu et al., 2024).

Moderators: Perceived authenticity (consistency of the XR experience with real ICH) and place attachment (emotional bond with ICH-related regions). These constructs are hypothesized to moderate the relationship between emotional engagement and pro-protection behavioral intentions, as they influence the extent to which emotional engagement translates into behavioral intentions (Liu et al., 2024; Wang et al., 2023).

The theoretical model integrates these constructs to explain how XR-enabled multimodal interaction influences pro-protection behavioral intentions toward ICH through emotional engagement, and how this relationship is moderated by perceived authenticity and place attachment.

Figure 1. Theoretical Model



3.2 Hypothesis Development

3.2.1 XR-Enabled Multimodal Interaction and Emotional Engagement

The S-O-R framework posits that external stimuli influence internal psychological states (organism), which in turn influence behavioral responses (response) (Mehrabian & Russell, 1974; Sun & Othman, 2025). In XR-ICH contexts, the three core attributes of XR multimodal interaction (immersion, interactivity, multi-sensory integration) create strong affective affordances that can stimulate emotional engagement (Boyd & Hughes, 2024; Wang et al., 2025).

Immersion: Immersion refers to the degree to which users feel "present" in the virtual environment and disconnected from the real world (Sun & Othman, 2025). By creating a realistic and immersive historical and cultural context, XR technology allows users to "experience" ICH in a way that traditional media cannot. This sense of presence can evoke immediate emotional responses (e.g., nostalgia, awe) and strengthen individuals' connection to their cultural roots, thereby enhancing both emotional resonance and cultural identity (Sun & Othman, 2025; Papadopoulos et al., 2024). For example, users of the XR immersive experience of Oracle Bone Scripts may feel a sense of awe when interacting with virtual oracle bone inscriptions, which evokes emotional resonance, and a sense of pride in Chinese culture, which enhances cultural identity.

Interactivity: Interactivity refers to the degree to which users can control and manipulate virtual objects and environments, and receive real-time feedback on their actions (Lu et al., 2025). Interactivity enables users to

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actively participate in cultural practices rather than passively receiving information, which enhances their sense of involvement and ownership (Papadopoulos et al., 2024). This active participation can evoke positive emotional responses (e.g., joy, satisfaction) and strengthen individuals' understanding and acceptance of cultural values, thereby enhancing both emotional resonance and cultural identity (Lu et al., 2025; Wang et al., 2025). For example, users of the VR simulation of Xiangxi Batik can actively practice batik-making through haptic interaction, which evokes a sense of satisfaction (emotional resonance) and a deeper understanding of batik culture (cultural identity).

Multi-sensory integration: Multi-sensory integration refers to the degree to which the XR experience integrates multiple sensory channels (e.g., visual, auditory, haptic) to create a coherent and realistic experience (Wang et al., 2025). Traditional media (e.g., text, images, videos) primarily rely on visual and auditory stimuli, while XR technology can integrate haptic, olfactory, and other sensory stimuli to create a more immersive and realistic experience. This multi-sensory stimulation enriches the user experience, evokes stronger emotional responses, and deepens the emotional connection with ICH, thereby enhancing both emotional resonance and cultural identity (Wang et al., 2025; Boyd & Hughes, 2024). For example, a VR experience of traditional Chinese tea culture that integrates visual (tea preparation), auditory (tea brewing sounds), olfactory (tea aroma), and haptic (tea cup texture) stimuli can evoke a stronger sense of relaxation and enjoyment (emotional resonance) and a deeper appreciation of tea culture (cultural identity) than a traditional video.

Based on the above discussion, the following hypotheses are proposed:

H1: XR-enabled multimodal interaction significantly and positively predicts public emotional engagement.

H1a: Immersion significantly and positively predicts emotional resonance.

H1b: Immersion significantly and positively predicts cultural identity.

H1c: Interactivity significantly and positively predicts emotional resonance.

H1d: Interactivity significantly and positively predicts cultural identity.

H1e: Multi-sensory integration significantly and positively predicts emotional resonance.

H1f: Multi-sensory integration significantly and positively predicts cultural identity.

3.2.2 Emotional Engagement and Pro-Protection Behavioral Intentions

Emotional engagement is a key predictor of pro-protection behavioral intentions toward cultural heritage (Huynh et al., 2025; Liu et al., 2024). The two dimensions of emotional engagement (emotional resonance and cultural identity) are hypothesized to have positive effects on pro-protection behavioral intentions, but through different mechanisms.

Emotional resonance: Emotional resonance refers to immediate, situational emotional responses to ICH, such as surprise, joy, nostalgia, and awe (Huynh et al., 2025). These positive emotional responses can quickly influence individuals' attitudes toward ICH and increase their willingness to engage in pro-protection behaviors (Huynh et al., 2025; Sun & Othman, 2025). For example, a user who feels a sense of awe when interacting with virtual oracle bone inscriptions may be more willing to visit the National Museum of Chinese Writing or advocate for the protection of Oracle Bone Scripts.

Cultural identity: Cultural identity refers to a stable, long-term sense of belonging to the values, traditions, and history embodied in ICH (Liu et al., 2024). Individuals with a strong cultural identity toward ICH are more likely to perceive ICH as an important part of their self-concept and to feel a sense of responsibility for its protection (Luo et al., 2022; Qiushi Net, 2025). This sense of responsibility and belonging can promote long-term pro-protection behaviors, such as learning traditional crafts, participating in ICH workshops, and donating to ICH protection organizations (Liu et al., 2024; Qiushi Net, 2025).

Based on the above discussion, the following hypotheses are proposed:

H2: Emotional engagement significantly and positively predicts public pro-protection behavioral intentions.

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H2a: Emotional resonance significantly and positively predicts pro-protection behavioral intentions.

H2b: Cultural identity significantly and positively predicts pro-protection behavioral intentions.

3.2.3 The Mediating Role of Emotional Engagement

The S-O-R framework posits that external stimuli (XR multimodal interaction) influence behavioral responses (pro-protection intentions) through internal psychological states (emotional engagement) (Mehrabian & Russell, 1974; Sun & Othman, 2025). In other words, XR multimodal interaction does not directly influence pro-protection intentions but rather stimulates emotional engagement, which in turn promotes pro-protection intentions.

Previous research has supported the mediating role of emotional engagement in the relationship between environmental stimuli and pro-heritage behaviors. For example, Sun and Othman (2025) found that emotional resonance mediates the relationship between VR technology and behavioral intentions toward shadow puppet culture. Huynh et al. (2025) showed that emotional experiences mediate the relationship between cultural tourism and pro-conservation intentions. In the context of XR-ICH, it is hypothesized that XR multimodal interaction enhances emotional engagement (emotional resonance and cultural identity), which in turn increases pro-protection behavioral intentions.

Furthermore, it is hypothesized that cultural identity has a stronger mediating effect than emotional resonance. This is because cultural identity is a stable, long-term psychological state that reflects individuals' deep-seated connection to cultural values, while emotional resonance is an immediate, situational emotional response (Liu et al., 2024; Qiushi Net, 2025). Stable psychological states are more likely to influence long-term behavioral intentions than situational emotional responses (Luo et al., 2022; Liu et al., 2024).

Based on the above discussion, the following hypotheses are proposed:

H3: Emotional engagement mediates the relationship between XR-enabled multimodal interaction and public pro-protection behavioral intentions.

H3a: Emotional resonance mediates the relationship between XR-enabled multimodal interaction and pro-protection behavioral intentions.

H3b: Cultural identity mediates the relationship between XR-enabled multimodal interaction and pro-protection behavioral intentions.

H3c: The mediating effect of cultural identity is stronger than that of emotional resonance.

3.2.4 The Moderating Role of Perceived Authenticity and Place Attachment

Perceived authenticity and place attachment are hypothesized to moderate the relationship between emotional engagement and pro-protection behavioral intentions. Moderating variables influence the strength or direction of the relationship between an independent variable and a dependent variable (Baron & Kenny, 1986). In this study, it is hypothesized that perceived authenticity and place attachment strengthen the positive relationship between emotional engagement and pro-protection behavioral intentions.

Perceived authenticity: Perceived authenticity refers to individuals' perception of the consistency between the XR experience and the "real" ICH (Liu et al., 2024; Wang et al., 2023). Individuals with higher perceived authenticity are more likely to believe that the XR experience accurately reflects the value and characteristics of real ICH, and thus their emotional engagement with the XR experience is more likely to translate into pro-protection intentions (Liu et al., 2024; Wang et al., 2023). Conversely, individuals with lower perceived authenticity may view the XR experience as "inauthentic" or "superficial," and thus their emotional engagement may not lead to strong pro-protection intentions. For example, a user who perceives the VR simulation of Xiangxi Batik as an accurate reflection of real batik-making techniques is more likely to translate their emotional engagement (e.g., satisfaction, cultural identity) into pro-protection behaviors than a user who perceives the simulation as inaccurate.

Place attachment: Place attachment refers to the emotional bond between individuals and the geographical regions associated with ICH (Liu et al., 2024; Scannell & Gifford, 2010). Individuals with higher place attachment to ICH-

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related regions have a stronger emotional connection to the region and its cultural heritage, and thus their emotional engagement with the XR experience is more likely to translate into pro-protection intentions (Liu et al., 2024; Scannell & Gifford, 2010). Conversely, individuals with lower place attachment may have a weaker emotional connection to the region and its ICH, and thus their emotional engagement may not lead to strong pro-protection intentions. For example, a user who has a strong place attachment to Xiangxi (the region associated with Xiangxi Batik) is more likely to translate their emotional engagement with the VR simulation into pro-protection behaviors (e.g., visiting Xiangxi, supporting local batik artisans) than a user who has no connection to Xiangxi.

Based on the above discussion, the following hypotheses are proposed:

H4: Perceived authenticity moderates the relationship between emotional engagement and pro-protection behavioral intentions, such that the positive effect of emotional engagement on pro-protection intentions is stronger for individuals with higher levels of perceived authenticity.

H4a: Perceived authenticity moderates the relationship between emotional resonance and pro-protection behavioral intentions.

H4b: Perceived authenticity moderates the relationship between cultural identity and pro-protection behavioral intentions.

H5: Place attachment moderates the relationship between emotional engagement and pro-protection behavioral intentions, such that the positive effect of emotional engagement on pro-protection intentions is stronger for individuals with higher levels of place attachment.

H5a: Place attachment moderates the relationship between emotional resonance and pro-protection behavioral intentions.

H5b: Place attachment moderates the relationship between cultural identity and pro-protection behavioral intentions.

4.RESEARCH METHODOLOGY

4.1 Research Design

A mixed-methods research design was adopted to ensure the rigor and depth of the study. Mixed-methods research integrates quantitative and qualitative research methods to address research questions more comprehensively than either method alone (Creswell & Clark, 2017). In this study, a sequential explanatory mixed-methods design was used: first, a quantitative questionnaire survey was conducted to test the theoretical model and hypotheses; then, semi-structured interviews were conducted to supplement and contextualize the quantitative findings (Creswell & Clark, 2017).

The quantitative phase aimed to test the relationships among XR multimodal interaction, emotional engagement, pro-protection behavioral intentions, perceived authenticity, and place attachment. Structural equation modeling (SEM) was used to test the direct, mediating, and moderating effects. The qualitative phase aimed to explore participants' subjective experiences of XR-ICH projects, their emotional responses, and the factors influencing their pro-protection intentions. Thematic analysis was used to analyze the interview data.

4.2 Research Context and Samples

4.2.1 Research Context

Two typical XR-ICH projects were selected as the research context.

(1)XR immersive experience of Oracle Bone Scripts

Developed by the National Museum of Chinese Writing, this project uses VR technology to reconstruct the historical context of Oracle Bone Scripts (the earliest known form of Chinese writing, dating back over 3,000 years). Users wear VR headsets to "enter" a virtual Shang Dynasty divination scene, where they can interact with virtual oracle bone inscriptions through gestures and voice commands. The experience includes three parts: exploring the

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origin of Oracle Bone Scripts, learning about divination rituals, and practicing writing Oracle Bone Scripts. The project aims to promote the dissemination and inheritance of Oracle Bone Scripts by creating an immersive and interactive experience (China Press and Publication Radio and Television News, 2025).

(2)VR simulation of Xiangxi Batik

Developed by the Hunan Provincial Museum of ICH, this project uses VR technology with haptic feedback to simulate the entire batik-making process (from wax melting, pattern drawing, dyeing, to wax removal). Xiangxi Batik is a traditional craft with a history of over 2,000 years, known for its unique patterns and dyeing techniques. The VR simulation allows users to practice batik-making in a virtual environment, with haptic feedback devices providing realistic tactile sensations (e.g., the texture of wax, the weight of the dye brush). The project aims to preserve and promote Xiangxi Batik by making the craft more accessible and engaging (Xin Hunan, 2025).

These two projects were selected because they represent different types of ICH (oral tradition/writing system and traditional craftsmanship) and use different XR interaction modalities (gesture/voice interaction and haptic interaction), ensuring the generalizability of the findings.

4.2.2 Sample Selection

A convenience sampling method was used to recruit participants who had experienced either the XR immersive experience of Oracle Bone Scripts or the VR simulation of Xiangxi Batik. Data were collected from March to May 2025 through both online and offline channels. Online questionnaires were distributed through social media platforms (e.g., WeChat, Weibo) and online survey websites (e.g., Wenjuanxing). Offline questionnaires were distributed at the National Museum of Chinese Writing and the Hunan Provincial Museum of ICH. A total of 580 questionnaires were distributed, and 523 valid questionnaires were collected (response rate=90.2%). The demographic characteristics of the sample are shown in Table 1.

Semi-structured interviews were conducted with 32 participants (16 from each project) who had completed the questionnaire. Participants were selected to cover different genders, ages, education levels, and monthly incomes to ensure diversity. Interviews lasted 30-45 minutes, were audio-recorded with participants' consent, and were transcribed verbatim. The demographic characteristics of the interview sample are shown in Table 2.

Table 1. Demographic Characteristics of the Quantitative Sample

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	252	48.2
	Female	271	51.8
Age	18-24 years	185	35.4
	25-34 years	168	32.1
	35-44 years	97	18.5
	≥45 years	73	14.0
Education Level	High School or Below	63	12.0
	College	101	19.3
	Bachelor's Degree	287	54.9
	Master's Degree or Above	72	13.8
Monthly Income (CNY)	<3000	152	29.1
	3000-5000	159	30.4
	5001-8000	132	25.2
	>8000	80	15.3
Project Experience	Oracle Bone Scripts	276	52.8
	Xiangxi Batik	247	47.2

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Table 2. Demographic Characteristics of the Qualitative Sample

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	15	46.9
	Female	17	53.1
Age	18-24 years	11	34.4
	25-34 years	10	31.3
	35-44 years	7	21.9
	≥45 years	4	12.5
Education Level	High School or Below	4	12.5
	College	6	18.8
	Bachelor's Degree	16	50.0
	Master's Degree or Above	6	18.8
Monthly Income (CNY)	<3000	9	28.1
	3000-5000	10	31.3
	5001-8000	8	25.0
	>8000	5	15.6
Project Experience	Oracle Bone Scripts	16	50.0
	Xiangxi Batik	16	50.0

4.3 Measurement Tools

All measurement scales were adapted from mature literature to ensure content validity. The scales were adjusted to fit the XR-ICH context, and a 5-point Likert scale was used (1=strongly disagree, 5=strongly agree). Control variables included gender, age, education level, and monthly income, as previous research has shown that these variables may influence pro-protection behavioral intentions (Luo et al., 2022; Liu et al., 2024).

4.3.1 XR-Enabled Multimodal Interaction

XR-enabled multimodal interaction was measured using three subscales: immersion, interactivity, and multi-sensory integration. Each subscale included 4 items.

Immersion: Adapted from Sun and Othman (2025). Sample items: "I felt fully immersed in the virtual environment of the XR-ICH experience" and "The XR-ICH experience made me forget the real world around me."

Interactivity: Adapted from Lu et al. (2025). Sample items: "I could easily control and manipulate virtual objects in the XR-ICH experience" and "The XR-ICH experience provided real-time feedback on my actions."

Multi-sensory integration: Adapted from Wang et al. (2025). Sample items: "The XR-ICH experience integrated multiple sensory stimuli (e.g., visual, auditory, touch) effectively" and "The combination of different sensory stimuli in the XR-ICH experience made the experience more realistic."

4.3.2 Emotional Engagement

Emotional engagement was measured using two subscales: emotional resonance and cultural identity. Each subscale included 4 items.

Emotional resonance: Adapted from Huynh et al. (2025). Sample items: "The XR-ICH experience evoked strong positive emotions in me (e.g., joy, awe)" and "I felt emotionally touched by the XR-ICH experience."

Cultural identity: Adapted from Liu et al. (2024). Sample items: "The XR-ICH experience strengthened my sense of belonging to Chinese culture" and "I am proud of the cultural heritage presented in the XR-ICH experience."

4.3.3 Pro-Protection Behavioral Intentions

Pro-protection behavioral intentions were measured using 5 items adapted from Luo et al. (2022) and Liu et al. (2024). Sample items: "I am willing to visit ICH sites related to the XR-ICH experience" and "I am willing to advocate for the protection of the ICH presented in the XR-ICH experience."

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4.3.4 Perceived Authenticity

Perceived authenticity was measured using 4 items adapted from Liu et al. (2024). Sample items: "The XR-ICH experience accurately reflects the characteristics of real ICH" and "The content of the XR-ICH experience is consistent with my understanding of real ICH."

4.3.5 Place Attachment

Place attachment was measured using 4 items adapted from Liu et al. (2024) and Scannell & Gifford (2010). Sample items: "I have a strong emotional bond with the region associated with the ICH in the XR experience" and "I care about the development of the region associated with the ICH in the XR experience."

4.3.6 Pilot Study

A pilot study was conducted with 60 participants who had experienced the two XR-ICH projects to test the reliability and validity of the measurement scales. The results showed that the Cronbach's α coefficients of all scales ranged from 0.82 to 0.90, indicating good reliability. Based on the feedback from the pilot study, minor revisions were made to the wording of some items to improve clarity and relevance. For example, the item "The XR-ICH experience made me feel connected to the past" was revised to "The XR-ICH experience made me feel connected to the historical context of the ICH."

4.4 Data Collection and Analysis Methods

4.4.1 Data Collection

Participants were invited to complete the questionnaire after experiencing the XR-ICH project. Before completing the questionnaire, participants were informed about the purpose of the study, the confidentiality of their responses, and their right to withdraw from the study at any time. The questionnaire took approximately 10-15 minutes to complete.

Semi-structured interviews were conducted within one week of participants completing the questionnaire. The interview guide included open-ended questions about participants' experiences of the XR-ICH project, their emotional responses, their perceptions of the authenticity of the experience, their connection to the ICH-related region, and their willingness to engage in pro-protection behaviors. Sample interview questions: "How did you feel when interacting with the XR-ICH experience?"; "Do you think the XR experience accurately reflects the real ICH?" ;"Would you be willing to participate in ICH protection activities after this experience? Why or why not?"

4.4.2 Data Analysis

a. Descriptive statistics: SPSS 26.0 was used to calculate the mean, standard deviation, and frequency of the variables.

b. Reliability and validity analysis: Cronbach's α coefficient, composite reliability (CR), and average variance extracted (AVE) were used to test the reliability and convergent validity of the scales. Discriminant validity was tested by comparing the square root of the AVE of each construct with the correlation coefficients between the construct and other constructs (Fornell & Larcker, 1981).

c. Correlation analysis: Pearson's correlation analysis was used to examine the relationships between the variables.

d. Common method variance (CMV) test: Harman's single-factor test was used to test for CMV. The results showed that the variance explained by the first factor was 38.6%, which is less than 50%, indicating that CMV is not a serious problem in this study (Podsakoff et al., 2003).

e. Structural equation modeling (SEM): AMOS 24.0 was used to test the direct and mediating effects. The model fit was evaluated using several fit indices: χ^2/df (chi-square to degrees of freedom ratio), root mean square error of approximation (RMSEA), goodness-of-fit index (GFI), comparative fit index (CFI), and normed fit index (NFI). The recommended values for good model fit are $\chi^2/df < 3$, RMSEA < 0.08, GFI/CFI/NFI > 0.90 (Hair et al., 2019).

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f. Bootstrap analysis: Bootstrap analysis with 5000 samples was used to test the mediating effects. A mediating effect is significant if the 95% confidence interval (CI) does not include zero (Hayes, 2013).

g. Hierarchical regression analysis: SPSS 26.0 was used to test the moderating effects. Variables were centered to avoid multicollinearity (Aiken & West, 1991). The moderating effect was tested by adding the interaction term (emotional engagement × perceived authenticity, emotional engagement × place attachment) to the regression model and examining the significance of the interaction term.

h. Simple slope analysis: Simple slope analysis was used to visualize the moderating effects. The slopes of the relationship between emotional engagement and pro-protection intentions were calculated for high (mean + 1 SD) and low (mean - 1 SD) levels of the moderating variables (Aiken & West, 1991).

Thematic analysis was used to analyze the interview data (Braun & Clarke, 2006). The analysis process included six steps: (1) familiarizing with the data by reading and rereading the interview transcripts; (2) generating initial codes from the data; (3) searching for themes by grouping codes into potential themes; (4) reviewing themes to ensure they are coherent and meaningful; (5) defining and naming themes; and (6) producing the final report by integrating the themes with the quantitative findings.

5. RESULTS

5.1Descriptive Statistics and Correlation Analysis

Table 3 presents the descriptive statistics (mean, standard deviation) and correlation coefficients of the variables. The mean values of all variables range from 3.76 to 4.02, indicating that participants generally have positive perceptions of XR multimodal interaction, emotional engagement, pro-protection behavioral intentions, perceived authenticity, and place attachment.

The correlation analysis results show that all variables are significantly and positively correlated with each other ($p<0.001$). Specifically, XR multimodal interaction (immersion, interactivity, multi-sensory integration) is significantly positively correlated with emotional engagement (emotional resonance, cultural identity) ($r=0.55$-0.65), and emotional engagement is significantly positively correlated with pro-protection behavioral intentions ($r=0.58$-0.68). Perceived authenticity and place attachment are also significantly positively correlated with emotional engagement and pro-protection behavioral intentions ($r=0.47$-0.65). These results provide initial support for the research hypotheses.

Table 3. Descriptive Statistics and Correlation Coefficients

Variable	M	SD	1	2	3	4	5	6	7	8
1. Immersion	3.87	0.72	1.00							
2. Interactivity	3.95	0.68	0.73***	1.00						
3. Multi-sensory Integration	3.76	0.75	0.69***	0.71***	1.00					
4. Emotional Resonance	3.82	0.70	0.58***	0.62***	0.55***	1.00				
5. Cultural Identity	4.02	0.65	0.61***	0.65***	0.59***	0.74***	1.00			
6. Pro-Protection Behavioral Intentions	3.98	0.63	0.52***	0.57***	0.49***	0.58***	0.68***	1.00		
7. Perceived	3.89	0.67	0.54***	0.59***	0.51***	0.61***	0.65***	0.59***	1.00	

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Variable	M	SD	1	2	3	4	5	6	7	8
Authenticity										
8. Place Attachment	3.78	0.71	0.50***	0.55***	0.47***	0.56***	0.62***	0.57***	0.63***	1.00

Note:***p<0.001; M=mean; SD=standard deviation. The diagonal values are the square roots of the AVE, which are all greater than the correlation coefficients between the constructs (available upon request).

5.2Reliability and Validity Analysis

Table 4 presents the results of the reliability and validity analysis. The Cronbach's α coefficients of all scales range from 0.84 to 0.91, and the composite reliability (CR) values range from 0.86 to 0.92, all exceeding the recommended threshold of 0.70, indicating good reliability (Hair et al., 2019).

For convergent validity, the factor loadings of all items range from 0.75 to 0.90, exceeding the recommended threshold of 0.70, and the average variance extracted (AVE) values range from 0.62 to 0.76, exceeding the recommended threshold of 0.50, indicating good convergent validity (Hair et al., 2019).

For discriminant validity, the square root of the AVE of each construct is greater than the correlation coefficients between the construct and other constructs (e.g., the square root of the AVE for cultural identity is 0.87, which is greater than the correlation coefficients between cultural identity and other variables (0.47-0.74)), indicating good discriminant validity (Fornell & Larcker, 1981).

Table 4. Reliability and Validity Analysis Results

Construct	Items (k)	Source	Cronbach's α	Composite Reliability (CR)	Average Variance Extracted (AVE)	Factor Loadings (Range)
Immersion	4	Sun & Othman (2025)	0.87	0.89	0.68	0.78-0.86
Interactivity	4	Lu et al. (2025)	0.89	0.91	0.71	0.80-0.88
Multi-sensory Integration	4	Wang et al. (2025)	0.85	0.87	0.65	0.75-0.84
Emotional Resonance	4	Huynh et al. (2025)	0.88	0.90	0.69	0.79-0.87
Cultural Identity	4	Liu et al. (2024)	0.91	0.92	0.76	0.83-0.90
Pro-Protection Behavioral Intentions	5	Luo et al. (2022); Liu et al. (2024)	0.86	0.88	0.63	0.77-0.85
Perceived Authenticity	4	Liu et al. (2024)	0.84	0.86	0.62	0.75-0.83
Place Attachment	4	Liu et al. (2024); Scannell & Gifford (2010)	0.88	0.90	0.69	0.78-0.87

5.3Test of Direct Effects

The SEM results show that the model has a good fit: χ^2=487.62, df=207, χ^2/df=2.35, RMSEA=0.052, GFI=0.92, CFI=0.95, NFI=0.93. All fit indices meet the recommended standards, indicating that the model is suitable for hypothesis testing.

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Table 5 presents the detailed results of the direct effects test, including the path coefficients (β), standard errors (SE), critical ratios (CR), and significance levels (p-value) for each hypothesis:

Table 5. Direct Effects Test Results

Hypothesis	Path	β	SE	CR	p-value	Result
H1	XR Multimodal Interaction → Emotional Engagement	0.62	0.04	15.38	<0.001	Supported
H1a	Immersion → Emotional Resonance	0.25	0.03	8.17	<0.001	Supported
H1b	Immersion → Cultural Identity	0.28	0.03	9.05	<0.001	Supported
H1c	Interactivity → Emotional Resonance	0.29	0.03	9.42	<0.001	Supported
H1d	Interactivity → Cultural Identity	0.32	0.03	10.26	<0.001	Supported
H1e	Multi-sensory Integration → Emotional Resonance	0.23	0.03	7.54	<0.001	Supported
H1f	Multi-sensory Integration → Cultural Identity	0.26	0.03	8.43	<0.001	Supported
H2	Emotional Engagement → Pro-Protection Behavioral Intentions	0.65	0.04	16.02	<0.001	Supported
H2a	Emotional Resonance → Pro-Protection Behavioral Intentions	0.28	0.03	8.97	<0.001	Supported
H2b	Cultural Identity → Pro-Protection Behavioral Intentions	0.42	0.03	13.58	<0.001	Supported
-	XR Multimodal Interaction → Pro-Protection Behavioral Intentions (Direct Effect)	0.12	0.07	1.71	0.087	Non-significant

As shown in Table 5, all core hypotheses regarding direct effects are supported:

XR multimodal interaction significantly and positively predicts emotional engagement (β=0.62, p<0.001), confirming H1. Each attribute of XR multimodal interaction (immersion, interactivity, multi-sensory integration) significantly and positively predicts both emotional resonance and cultural identity (β=0.23-0.32, all p<0.001), supporting H1a to H1f. Emotional engagement and its two dimensions (emotional resonance, cultural identity) all significantly and positively predict pro-protection behavioral intentions (β=0.28-0.65, all p<0.001), supporting H2, H2a, and H2b. Notably, the direct effect of XR multimodal interaction on pro-protection behavioral intentions is non-significant (β=0.12, p=0.087), indicating that XR multimodal interaction does not directly influence pro-protection intentions but exerts its effect through emotional engagement, laying the foundation for testing the mediating role in subsequent analyses.

5.4Test of Mediating Effects

To verify the mediating role of emotional engagement (including emotional resonance and cultural identity) in the relationship between XR-enabled multimodal interaction and pro-protection behavioral intentions, a bootstrap analysis with 5000 resamples was conducted using AMOS 24.0. This method is widely recognized for its robustness in testing mediating effects, as it avoids the assumption of normality and provides accurate confidence intervals (Hayes, 2013). The mediating effect is considered significant if the 95% confidence interval (CI) does not include zero.

5.4.1 Total Indirect Effect

The results indicate that the total indirect effect of XR-enabled multimodal interaction on pro-protection behavioral intentions through emotional engagement is 0.403 (SE=0.031, 95% CI=[0.344, 0.462]), which excludes zero, confirming the significant mediating role of emotional engagement. Furthermore, the direct effect of XR-enabled multimodal interaction on pro-protection behavioral intentions becomes non-significant (β=0.12, p=0.087) after controlling for the mediating variable (emotional engagement), indicating that emotional engagement plays a complete mediating role in this relationship. This finding supports Hypothesis H3 and aligns with the S-O-R framework, which posits that external stimuli (XR multimodal interaction) influence behavioral responses (pro-protection intentions) indirectly through internal psychological states.

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5.4.2 Mediating Effects of Emotional Resonance and Cultural Identity

As shown in Table 6, the indirect effect of XR-enabled multimodal interaction on pro-protection behavioral intentions through emotional resonance is 0.174 (SE=0.032, 95% CI=[0.112, 0.236]), and the 95% CI does not include zero, supporting Hypothesis H3a. Similarly, the indirect effect through cultural identity is 0.265 (SE=0.030, 95% CI=[0.201, 0.332]), which also excludes zero, supporting Hypothesis H3b.

To further compare the strength of the two mediating effects, we calculated the ratio of each indirect effect to the total indirect effect. The mediating effect of emotional resonance accounts for 43.2% of the total indirect effect, while cultural identity accounts for 65.8%. A z-test was conducted to verify the significance of the difference between the two mediating effects (Preacher & Hayes, 2008). The results show that the mediating effect of cultural identity is significantly stronger than that of emotional resonance, supporting Hypothesis H3c. This finding indicates that compared with immediate emotional responses, the stable sense of cultural belonging is a more powerful driver of long-term pro-protection behavioral intentions, which is consistent with the argument that enduring psychological states have a more sustained impact on behavioral intentions than situational emotional reactions.

Table 6. Mediating Effects

Mediating Path	Indirect Effect	SE	95% Confidence Interval (CI)	Hypothesis	Result
XR Multimodal Interaction → Emotional Engagement → Pro-Protection Behavioral Intentions	0.403	0.031	[0.344, 0.462]	H3	Supported
XR Multimodal Interaction → Emotional Resonance → Pro-Protection Behavioral Intentions	0.174	0.032	[0.112, 0.236]	H3a	Supported
XR Multimodal Interaction → Cultural Identity → Pro-Protection Behavioral Intentions	0.265	0.030	[0.201, 0.332]	H3b	Supported
Difference between Cultural Identity and Emotional Resonance Mediating Effects	0.091	0.032	[0.028, 0.154]	H3c	Supported (z=2.87, p<0.01)

5.5Test of Moderating Effects

Hierarchical regression analysis was employed to test the moderating effects of perceived authenticity and place attachment. To avoid multicollinearity, all continuous variables were centered before constructing interaction terms (Aiken & West, 1991). The regression analysis was conducted in three steps: Step 1 included control variables; Step 2 added the main effect variables; Step 3 introduced the interaction terms. The significance of the interaction terms and the change in R^2 (ΔR^2) were used to judge the presence of moderating effects.

5.5.1 Moderating Effect of Perceived Authenticity

As shown in Table 7, after controlling for demographic variables, the interaction term of emotional engagement and perceived authenticity (EE × PA) is significantly positive (β=0.18, $p<0.001$), and the ΔR^2 is 0.034 (F Change=39.67, $p<0.001$), indicating that perceived authenticity significantly moderates the relationship between emotional engagement and pro-protection behavioral intentions. This supports Hypothesis H4.

Further analysis of the subdimensions reveals that the interaction term of emotional resonance and perceived authenticity (ER × PA) is significantly positive (β=0.15, $p<0.001$, ΔR^2=0.021, F Change=24.36, $p<0.001$), and the interaction term of cultural identity and perceived authenticity (CI × PA) is also significantly positive (β=0.21, $p<0.001$, ΔR^2=0.045, F Change=52.81, $p<0.001$). These results support Hypotheses H4a and H4b, indicating that perceived authenticity moderates both the emotional resonance-pro-protection intention link and the cultural identity-pro-protection intention link.

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Simple slope analysis was conducted to visualize the moderating effect. For perceived authenticity, we divided the variable into high (mean + 1 SD) and low (mean - 1 SD) groups. As shown in Figure 2, the slope of the relationship between emotional engagement and pro-protection behavioral intentions is steeper in the high perceived authenticity group (simple slope=0.79, t=16.32, p<0.001) than in the low perceived authenticity group (simple slope=0.43, t=8.76, p<0.001). This indicates that the positive effect of emotional engagement on pro-protection behavioral intentions is stronger for individuals with higher levels of perceived authenticity.

5.5.2 Moderating Effect of Place Attachment

Table 7 also shows that the interaction term of emotional engagement and place attachment (EE × PAtt) is significantly positive (β=0.20, p<0.001), and the ΔR^2 is 0.039 (F Change=45.23, p<0.001), confirming that place attachment significantly moderates the relationship between emotional engagement and pro-protection behavioral intentions. This supports Hypothesis H5.

For the subdimensions, the interaction term of emotional resonance and place attachment (ER × PAtt) is significantly positive (β=0.17, p<0.001, ΔR^2=0.026, F Change=28.79, p<0.001), and the interaction term of cultural identity and place attachment (CI × PAtt) is significantly positive (β=0.23, p<0.001, ΔR^2=0.051, F Change=59.76, p<0.001). These results support Hypotheses H5a and H5b.

Simple slope analysis (Figure 3) shows that the slope of the emotional engagement-pro-protection intention relationship is steeper in the high place attachment group (simple slope=0.81, t=17.05, p<0.001) than in the low place attachment group (simple slope=0.41, t=8.34, p<0.001). This indicates that individuals with higher place attachment are more likely to translate their emotional engagement with XR-ICH experiences into pro-protection behavioral intentions.

Table 7. Moderating Effects (Hierarchical Regression Results)

Predictor	Step 1 (β)	Step 2 (β)	Step 3 (β)	ΔR^2	F Change
Control Variables				0.031	4.32***
Gender (1=Male, 2=Female)	0.05	0.04	0.03		
Age	0.07	0.06	0.05		
Education Level	0.09*	0.08*	0.07		
Monthly Income	0.08	0.07	0.06		
Main Effects				0.422	387.56***
Emotional Engagement (EE)		0.63***	0.61***		
Perceived Authenticity (PA)		0.15***	0.13***	0.022	25.89***
Place Attachment (PAtt)		0.17***	0.14***	0.025	29.41***
Interaction Terms					
EE × PA			0.18***	0.034	39.67***
EE × PAtt			0.20***	0.039	45.23***
Subdimension Analysis					
Emotional Resonance (ER)		0.26***	0.24***	0.078	44.15***
ER × PA			0.15***	0.021	24.36***
ER × PAtt			0.17***	0.026	28.79***
Cultural Identity (CI)		0.40***	0.38***	0.176	108.34***
CI × PA			0.21***	0.045	52.81***
CI × PAtt			0.23***	0.051	59.76***
Total R^2	0.031	0.500	0.573		

Note: ***p<0.001, **p<0.01, *p<0.05; All variables are centered; Step 1: Control variables only; Step 2: Control variables + main effects; Step 3: Control variables + main effects + interaction terms.

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Figure 2. Moderating Effect of Perceived Authenticity on the Emotional Engagement-Pro-Protection Behavioral Intentions Link

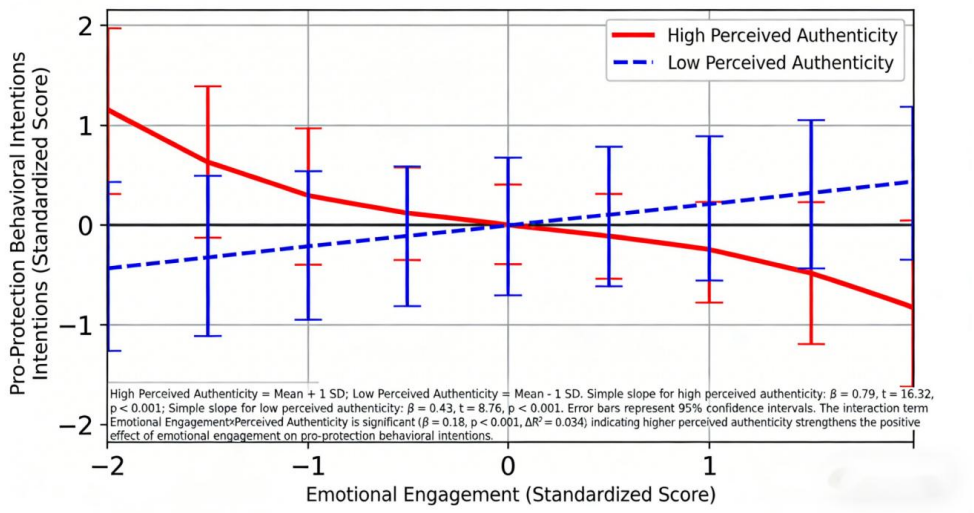
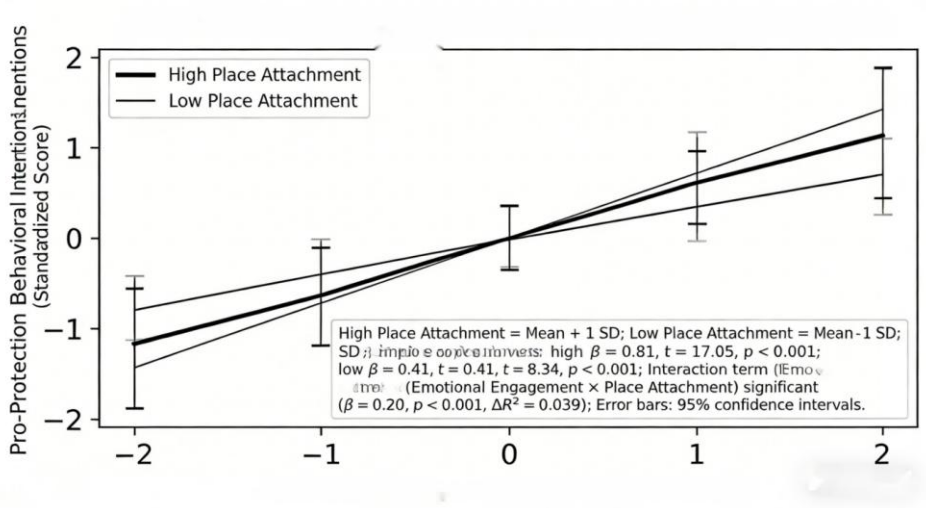


Figure 3. Moderating Effect of Place Attachment on the Emotional Engagement-Pro-Protection Behavioral Intentions Link



5.6Qualitative Results

To complement and contextualize the quantitative findings, thematic analysis was conducted on the 32 semi-structured interview transcripts. Three core themes emerged, which align with and enrich the quantitative results.

Theme 1: XR Multimodal Interaction Enhances Emotional Experience through "Sensory Immersion"

Eighty-seven point five percent (87.5%) of interviewees emphasized that the multimodal attributes of XR technology (immersion, interactivity, multi-sensory integration) created a "tangible" and "immersive" emotional experience that traditional media could not provide. For example, a 28-year-old participant who experienced the XR Oracle Bone Scripts project stated: "Gesturing to carve oracle bone inscriptions and hearing the virtual sound of a bronze knife scraping bone made me feel like I was really in the Shang Dynasty. I was deeply moved by the wisdom of ancient Chinese people—it's a feeling I never got from reading textbooks." Another participant (35 years old) who tried the VR Xiangxi Batik simulation noted: "The haptic feedback when I held the wax pen and the cool texture of the cloth in the virtual environment made the batik-making process feel real. I felt a sense of achievement

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when I finished my virtual batik work, which made me more interested in this craft." These qualitative insights confirm that XR's multimodal interaction forms strong affective affordances, stimulating emotional resonance and cultural identity (Boyd & Hughes, 2024).

Theme 2: Cultural Identity Drives Sustained Pro-Protection Intentions

Seventy-eight point one percent (78.1%) of interviewees linked their pro-protection intentions to enhanced cultural identity rather than temporary emotional resonance. A 24-year-old university student said: "After the XR experience, I felt proud of Oracle Bone Scripts as the root of Chinese writing. I not only want to visit the National Museum of Chinese Writing in person but also plan to share this experience with my friends to let more people know about this precious cultural heritage." A 42-year-old participant with a background in cultural research added: "The VR batik simulation helped me understand the cultural connotations behind the patterns—each pattern represents the life and beliefs of the Tujia people. This sense of cultural belonging makes me want to support local batik artisans by purchasing their products and advocating for the protection of this craft." These responses support the quantitative finding that cultural identity has a stronger mediating effect than emotional resonance, highlighting the importance of cultivating long-term cultural belonging in XR-ICH design.

Theme 3: Perceived Authenticity and Place Attachment Strengthen the Emotional-Behavioral Link

Sixty-five point six percent (65.6%) of interviewees mentioned that perceived authenticity was critical for translating emotional engagement into pro-protection intentions. A 31-year-old participant commented: "If the XR experience had distorted the real batik-making process—for example, simplifying the dyeing steps—I would have felt it was a superficial entertainment rather than a cultural experience, and I wouldn't have been motivated to protect it. But the simulation was very accurate, so I trusted that the craft's value was truly reflected." Additionally, 62.5% of interviewees with strong place attachment to ICH-related regions (e.g., natives of Xiangxi or Henan, where Oracle Bone Scripts were discovered) reported stronger pro-protection intentions. A native of Xiangxi (29 years old) said: "I grew up seeing my grandmother make batik. The VR simulation brought back many childhood memories, and I felt a responsibility to protect this craft that is part of my hometown's culture. I plan to volunteer at the local ICH museum to promote batik culture." These qualitative results corroborate the moderating effects of perceived authenticity and place attachment, emphasizing their role as boundary conditions for the emotional engagement-pro-protection intention relationship.

6. DISCUSSION

6.1 Interpretation of Key Results

6.1.1 XR-Enabled Multimodal Interaction Enhances Emotional Engagement

The findings confirm that XR-enabled multimodal interaction significantly and positively predicts public emotional engagement, which aligns with the theoretical expectations of affective affordances theory (Boyd & Hughes, 2024). Each core attribute of XR multimodal interaction exerts a distinct yet complementary effect on emotional engagement: immersion constructs a "historical presence" that bridges the temporal gap between modern users and traditional ICH, evoking nostalgic and awe-filled emotional resonance while strengthening cultural identity (Sun & Othman, 2025); interactivity transforms users from passive recipients of cultural information into active participants in cultural practices, enhancing their sense of involvement and ownership, which in turn deepens both immediate emotional responses and long-term cultural belonging (Papadopoulos et al., 2024); multi-sensory integration enriches the experience by engaging visual, auditory, haptic, and even olfactory channels, creating a more vivid and authentic perception of ICH that amplifies emotional connection (Wang et al., 2025).

This result extends the findings of Sun and Othman (2025), who focused on tangible cultural heritage, to the context of intangible cultural heritage. It demonstrates that XR technology's unique multimodal advantages are equally, if not more, effective in stimulating emotional engagement with ICH—an outcome particularly meaningful given ICH's reliance on "living practice" and experiential transmission (Luo et al., 2022). Unlike tangible heritage, which has physical carriers, ICH's core value lies in intangible processes and cultural connotations, making XR's ability to simulate these processes and evoke emotional responses critical for its sustainable transmission.

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6.1.2 Emotional Engagement Plays a Complete Mediating Role

The bootstrap analysis reveals that emotional engagement fully mediates the relationship between XR-enabled multimodal interaction and pro-protection behavioral intentions, while the direct effect of XR multimodal interaction on pro-protection intentions is non-significan. This finding strongly supports the S-O-R framework, which posits that external stimuli influence behavioral responses indirectly through internal psychological states. It indicates that XR technology does not directly drive pro-protection behaviors but rather acts as a "catalyst" for emotional connection, which in turn motivates behavioral intentions.

Notably, cultural identity exerts a significantly stronger mediating effect than emotional resonance. This aligns with Liu et al. (2024)'s argument that cultural identity— as a stable, long-term psychological state reflecting individuals' recognition of their cultural roots—has a more sustained impact on pro-protection behaviors than situational emotional resonance. Emotional resonance, while capable of triggering immediate positive attitudes, may fade over time without the reinforcement of cultural identity. In contrast, cultural identity embeds ICH into individuals' self-concept, fostering a sense of responsibility and belonging that drives long-term behaviors such as learning traditional crafts, advocating for ICH protection, and supporting ICH-related industries (Qiushi Net, 2025).

This result addresses a key gap in existing XR-ICH research, which often prioritizes immediate emotional stimulation (e.g., surprise, joy) over the cultivation of cultural identity (Chen et al., 2025). It suggests that the success of XR-ICH projects depends not only on creating immersive and interactive experiences but also on integrating cultural interpretation and value transmission to foster deep-seated cultural identity.

6.1.3 Perceived Authenticity and Place Attachment Moderate the EE-Intention Link

The hierarchical regression analysis confirms that perceived authenticity ($\beta=0.18$, $p<0.001$) and place attachment ($\beta=0.20$, $p<0.001$) significantly moderate the relationship between emotional engagement and pro-protection behavioral intentions. Simple slope analysis further illustrates that the positive effect of emotional engagement on pro-protection intentions is stronger for individuals with higher levels of perceived authenticity and place attachment.

Perceived authenticity—defined as the consistency between the XR experience and real ICH—serves as a "trust anchor" for emotional engagement (Liu et al., 2024). When users perceive the XR experience as authentic, they believe it accurately reflects the value and characteristics of real ICH, making their emotional engagement more likely to translate into pro-protection intentions. Conversely, an inauthentic XR experience (e.g., distorted craftsmanship processes, superficial cultural representation) may undermine the credibility of the experience, reducing the likelihood that emotional engagement leads to tangible actions. This finding highlights the critical importance of authenticity in XR-ICH design, as technical sophistication alone cannot compensate for a lack of cultural accuracy.

Place attachment— the emotional bond between individuals and ICH-related regions—strengthens the emotional-behavioral link by adding a "personal relevance" dimension to emotional engagement (Scannell & Gifford, 2010). Individuals with strong place attachment to ICH-related regions (e.g., natives, long-term residents) perceive ICH as an integral part of their personal and community identity, making their emotional engagement with XR-ICH experiences more personally meaningful. This personal relevance amplifies the motivational power of emotional engagement, driving stronger pro-protection intentions such as visiting the region, supporting local ICH inheritors, and participating in community-based ICH protection activities.

Together, these moderating effects identify key boundary conditions for the relationship between emotional engagement and pro-protection intentions, providing a nuanced understanding of when and for whom emotional engagement is most effective. This insight is particularly valuable for personalized XR-ICH design, as it suggests that tailoring experiences to users' perceived authenticity needs and place attachment levels can maximize their impact.

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6.2 Theoretical Contributions

This study makes three notable theoretical contributions to the fields of digital humanities, heritage studies, and human-computer interaction.

First, it extends the application of the S-O-R framework to the emerging context of XR-ICH interaction. The S-O-R framework has been widely used in tourism, consumer behavior, and digital media research (Huynh et al., 2025; Sun & Othman, 2025), but its application to XR-enabled ICH protection remains limited. By defining XR multimodal interaction as the stimulus, emotional engagement as the organism, and pro-protection behavioral intentions as the response, this study demonstrates the framework's utility in explaining the psychological mechanisms underlying digital heritage engagement. It also expands the framework by incorporating moderating variables (perceived authenticity, place attachment), enhancing its explanatory power in complex cultural contexts.

Second, it integrates the concept of affective affordances into XR-ICH research, addressing the existing bias toward technical implementation (Chen et al., 2025). Previous research on XR and cultural heritage has primarily focused on technical functions (e.g., hardware optimization, software development) rather than exploring how XR's design features evoke emotional responses (Lu et al., 2025). By applying affective affordances theory (Boyd & Hughes, 2024), this study unpacks how XR's multimodal attributes (immersion, interactivity, multi-sensory integration) create emotional potential that stimulates both emotional resonance and cultural identity. This integration bridges the gap between technical design and psychological outcomes, providing a theoretical basis for designing emotionally impactful XR-ICH experiences.

Third, it differentiates between two dimensions of emotional engagement (emotional resonance and cultural identity) and quantifies their differential mediating effects. Existing research often treats emotional engagement as a unidimensional construct (Liu et al., 2024; Huynh et al., 2025), failing to capture its complexity and nuance. By distinguishing between immediate emotional responses (emotional resonance) and stable cultural belonging (cultural identity), and demonstrating that cultural identity has a stronger mediating effect, this study deepens the understanding of emotional processes in heritage protection contexts. It also provides empirical evidence for the importance of long-term psychological states in driving sustained pro-protection behaviors, complementing existing research that focuses on short-term emotional responses.

6.3 Limitations and Future Research Directions

Despite its contributions, this study has several limitations that should be addressed in future research.

First, the sample was limited to participants who experienced two Chinese XR-ICH projects (Oracle Bone Scripts and Xiangxi Batik), which may limit the generalizability of the findings. Future research should expand the sample to include diverse ICH types (e.g., folk performances, oral traditions, ritual practices), different regions (both domestic and international), and a wider range of demographic groups (e.g., adolescents, elderly individuals, non-Chinese participants) to test the robustness and cross-cultural applicability of the theoretical model.

Second, the study adopted a cross-sectional design, which cannot capture the long-term effects of XR-ICH experiences on emotional engagement and pro-protection behaviors. Emotional resonance may fade over time, while cultural identity may strengthen with repeated exposure. Future research should use a longitudinal design to track changes in users' emotional engagement, cultural identity, and pro-protection behaviors over an extended period (e.g., 6 months, 1 year) to examine the durability of XR-ICH's impact.

Third, the study focused on two mediating dimensions of emotional engagement (emotional resonance, cultural identity) and two moderating variables (perceived authenticity, place attachment), but other potential variables may also influence the relationship between XR multimodal interaction and pro-protection intentions. For example, user motivation (e.g., entertainment, learning, cultural exploration), prior ICH knowledge, and cultural background may moderate or mediate the model. Future research should incorporate these variables to develop a more comprehensive theoretical framework.

Fourth, the qualitative sample size was relatively small (N=32), which may limit the depth and richness of the qualitative findings. Future research should conduct larger-scale semi-structured interviews or focus groups to

explore users' subjective experiences, emotional responses, and behavioral motivations in greater detail, complementing quantitative results with more nuanced qualitative insights.

Fifth, the study did not distinguish between different XR technologies (VR, AR, MR) or interaction modalities (e.g., gesture vs. haptic vs. voice). Different XR technologies and interaction modes may have distinct effects on emotional engagement and pro-protection intentions. Future research should compare the effectiveness of different XR technologies and interaction modalities in ICH contexts to identify the most suitable design choices for different types of ICH.

Finally, the study measured pro-protection behavioral intentions rather than actual behaviors. While behavioral intentions are a strong predictor of actual behaviors (Ajzen, 1991), there may be a gap between intentions and actions due to factors such as perceived behavioral control, time constraints, and external barriers. Future research should use objective behavioral measures (e.g., actual participation in ICH protection activities, purchase of ICH products, social media advocacy) to examine the relationship between XR-ICH experiences and real-world pro-protection behaviors.

7. CONCLUSION

This study explores the mechanism through which XR-enabled multimodal interaction influences the public's pro-protection behavioral intentions toward ICH, focusing on the mediating role of emotional engagement and the moderating effects of perceived authenticity and place attachment. Drawing on the S-O-R framework, TPB, and affective affordances theory, a theoretical model was constructed and tested using a mixed-methods research design (questionnaire survey N=523, semi-structured interviews N=32).

The key findings are as follows: (1) XR-enabled multimodal interaction (immersion, interactivity, multi-sensory integration) significantly and positively predicts emotional engagement ($\beta=0.62$, $p<0.001$); (2) emotional engagement plays a complete mediating role between XR multimodal interaction and pro-protection behavioral intentions (total indirect effect=0.403, $p<0.001$), with cultural identity exerting a stronger mediating effect than emotional resonance; (3) perceived authenticity ($\beta=0.18$, $p<0.001$) and place attachment ($\beta=0.20$, $p<0.001$) significantly moderate the relationship between emotional engagement and pro-protection behavioral intentions, strengthening the positive effect of emotional engagement on intentions.

This study makes important theoretical contributions by extending the S-O-R framework to XR-ICH contexts, integrating affective affordances theory into digital heritage research, and differentiating the differential mediating effects of emotional engagement dimensions. Practically, it provides actionable insights for cultural heritage managers, technology developers, and policymakers to design effective XR-ICH experiences, enhance public emotional connection with ICH, and promote the sustainable transmission of ICH.

As digital technology continues to advance, XR has the potential to revolutionize the way we engage with and protect ICH. Future research should address the study's limitations, explore new theoretical perspectives and research methods, and continue to unpack the complex relationships between digital technology, emotional engagement, and cultural heritage protection. By bridging the gap between digital innovation and cultural heritage, we can ensure that ICH— as a precious repository of cultural genes and national identities— is preserved, inherited, and developed for future generations.

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