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Multisensory Interaction and User Experience in Digital Displays of Intangible Cultural Heritage: The Case of Shadow Puppetry

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Abstract. Museums and cultural institutions are exploring using multimodal immersive experiences to improve the dissemination of intangible cultural heritage, taking advantage of the rapid advancements being made in artificial intelligence (AI) and extended reality (XR) technologies. This paper will investigate the performance of intangible cultural heritage through the example of shadow puppetry, looking at two case studies: The Xi'an Ming-Qing Shadow Puppetry Art Museum located in China, and the National Touring Exhibition "Shadow Puppetry in the World". A combination of literature review and comparative case studies were used to compare the user experience, emotional response and cultural cognition created through XR and traditional static exhibitions. Results showed that using multimodal interactions increases audience's sense of immersion, level of engagement and efficiency with cultural understanding, building deeper emotional connections to the culture and enhancing the audience's identification with it. Digital exhibitions also have limitations, for example there are currently weak operational mechanisms in terms of sustainability for the dissemination of digital content and long-term user engagement. Based on the results of this study a "Multisensory -XR Experience Framework" is proposed to support the digital revitalization of performative intangible cultural heritage at the level of practice and theory, across the four dimensions of sensory integration, interaction pathways, affective design and communication extension.

Keywords: Digital Humanities, Multimodal Interaction, Extended Reality (XR), Museum Experience, Cultural Cognition

1. Introduction

Museums are adapting to new technologies like artificial intelligence (AI), extended reality (XR), and multisensory interaction design. Traditional static exhibitions are moving toward digital displays that are immersive and participatory. The single visual presentation of exhibitions will not engage new audiences, because they want emotional and interactive experiences within the culture. XR has become the technology of choice for immersive cultural heritage displays, as it allows for reconstruction of the spatial aspect of heritage, multiple modes of display, and real-time interactivity. Evidence shows that when exhibitions incorporate visual, sound, and touch into their exhibition,

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visitors experience a greater level of presence, understanding, and motivation to participate [1]. The research available on XR and multisensory visualizations of ICH has several gaps: First, existing XR and multisensory displays of intangible cultural heritage primarily focus on artefact-based heritage, while there is little or no focus on non-artefact-based forms such as performance based, narrative based, or time based intangible cultural heritage (for example, shadow puppetry). Secondly, while many studies exist on the technical implementation of digital ICH projects, there are few studies that evaluate our interaction with these digital ICH projects. These are called user experience studies. They look at how digital ICH project can provide emotional, immersive, and identity through our culture [2]. Most digital ICH projects focus on short-term, temporary displays with no research on sustainable ways to share, engage with, and use them over time [3]. To help fill in these knowledge gaps, this paper presents two related case studies centered around shadow puppetry: Xi'an Ming-Qing Shadow Puppet Art Museum and the "Shadow Play in the World" traveling exhibit at Chengdu Museum. This research compares both cases using various metrics such as exhibit rationale, audience response, and cultural sharing and uses these cases to address how multisensory engagement can recreate the context of the performance and paths of understanding ICH through digital means. Thus, this paper proposes a "Multisensory-XR Design Framework" to guide the design of digital exhibitions of performance-based intangible cultural heritage, providing both theoretical grounding and practical direction for future designers of intangible cultural heritage exhibitions.

2. Research background: the cultural characteristics and display difficulties of shadow puppetry

Shadow puppetry is a highly representative form of traditional Chinese art, integrating various artistic elements such as sculpture, painting, opera, music and literature, and is known as a "living intangible cultural heritage". Since 2006, it has been included in the National Intangible Cultural Heritage List and was recognized by UNESCO as a Representative Work of the Intangible Cultural Heritage of Humanity in 2011. The performance of shadow puppetry mainly involves manipulating the silhouettes of characters behind the scenes and combining singing, Musical Instruments and lighting to tell stories. It has distinct visual expressiveness and narrative style, embodying the aesthetic concept of the integration of "form", "sound" and "meaning" in traditional Chinese culture.

However, with the acceleration of social pace and the change of dissemination methods, this ancient art is facing more and more challenges, such as a gradually decreasing audience, a gap in the inheritance group, and a single dissemination method. In museums, shadow puppet exhibitions are mostly displayed in static cases, lacking dynamic performances and interaction with the audience, which makes it difficult for people to truly understand its unique charm as a "living" art. Especially for art forms like shadow puppetry that rely on performance, sound and changes in light and shadow to create a complete experience, if only images and objects are displayed, it is very likely to cause a gap where "one can only see the form but not feel the content".

Digital technologies like XR, VR, and AR have been rapidly developing over the past few years, creating new opportunities for displaying intangible cultural heritage. Increased research has focused on how to improve the audience's sense of participation and the audience's sense of understanding of culture with multi-sensory and immersive technologies. Lin argued that the integration of the emotional design concept and XR technologies will create greater emotional participation and cultural resonance for the audience. This research also states that the two main factors affecting acceptance of digital intangible cultural heritage displays, specifically with AR/VR technologies, are immersion and practical application [4]. In addition, Lee and King examined how AR/VR

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technologies can promote cultural tourism and build sustainable connections between communities in terms of cultural sustainability [5]. Qiu found that gamifying intangible cultural heritage will help attract youth to ongoing participation and interest and will help create long-term dissemination paths for intangible cultural heritage [6].

An increasing number of exhibition projects are incorporating multi-sensory experiences, such as sound, light and shadow, projection and motion sensing, with immersive technologies to restore the feeling of presence and participation in cultural practices. The Chengdu Museum's permanent exhibition "Shadow Dance in All Phenomena" of shadow puppetry; the Augmented Reality project at the Xi'An Ming and Qing Dynasty Shadow Puppetry Art Museum; and the national touring exhibition "Shadow Play in the World" are all examples of modern technology being used to revive the dynamic appeal of shadow puppetry. All three examples also seek to find a balance between technology and culture while offering new ways to display and research digitally disseminating traditional intangible cultural heritage.

This paper uses the above three real-world examples as case studies to study and analyze the potential of using multi-sensory design and XR technologies to address the issues and challenges associated with digitally displaying shadow puppetry and its relevance and inspiration to the transmission of intangible cultural heritage today.

3. Literature references

Scholarly work has been focused on the incorporation of multi-sensory experiences into cultural heritage exhibitions in recent years. Traditionally, the predominant way of exhibiting was through visual impacts. Studies by Luo, Doucé, and Nys systematically reviewed 331 multi-sensory studies in museums and developed a complete theoretical and technical framework for creating multi-sensory experiences in museums. They identified sensory elements such as smell, touch, and sound maximize visitor engagement, immersion and satisfaction, and advocated for a change in the context of sensorial stimulation from being simply technological augmentation to being a tool for narrative and cultural meaning creation [7]. This theoretical basis supports recent efforts to apply XR and AI technologies to intangible cultural heritage (ICH), particularly in performance-based traditions. For instance, Yu has built a VR system to recreate Cantonese opera and based on user testing results, determined that the immersive storytelling experience generated improved user understanding of and interest in Cantonese opera [8]. Liu also found that users' perception of usefulness and immersion have a significant effect on their acceptance of AR/VR based ICH experiences; however, authenticity continues to be a barrier. At the same time, Chen, Li, and Zhang outlined an embodied cognition model to create ICH exhibitions, emphasizing that understanding and memory develop through physical interaction, multi-sensory contexts, and emotional identification [9]. In their educational research, Wang established that embodied, controller free XR systems such as their multisensory VR platform to experience murals from the Kizil Grottoes greatly assist in cultural learning, creating an emotional connection, and providing broader accessibility in alignment with sustainable development goals [10]. Together these studies indicate a shift from content-based to experience-based design in the ICH and the need for more sophisticated, user-centered, and sustainable applications for the presentation of ICH. This study uses the previous literature to present a foundation for organizing the literature on four overlapping themes: multi-sensory experiences, XR/AI applications, emotions and cognition through movement, and the sustainability impacts of these themes. This organization serves as a framework through which research has been established, as well as the structure for analysis in future case studies of shadow puppetry, which will be the subject of later chapters in this work.

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4. Methodology

The purpose of this paper is to compare and contrast the traditional and multimodal XR (extended reality) exhibition methods to relay the shadow puppet culture while providing the user with an enhanced experience of movement and visibility through the four areas of immersion, emotional response, cultural understanding and engagement. As such, the research will answer the following research questions：

1. How does multimodal XR change how audiences view and interact with shadow puppet culture?

2. Does immersive and traditional presentation enhance user experience?

3. Does presentation type heavily affect users' emotional resonance, knowledge acquisition, and interactions?

This research study utilizes a case study methodology obtain qualitative data and few quantitative data. The analyses of two different case studies will provide a systematic analysis of all the research questions above.

Case Selection Criteria

• Representativeness: Using traditional examples of shadow puppets and a digital example of exhibiting shadow puppets；

• Data Accessibility: Data provided is open to the public and also through user feedback and academic study；

• Diversity and Contrast: Clear differences in exhibition strategies used, design for interactivity in exhibitions, and audience types；

The selected cases are：

• Traditional Case: Xi'an Ming-Qing Shadow Puppet Art Museum (a static exhibition in a traditional exhibition space)

• Digital Case: "Shadow Play of the World" National Shadow Puppet Touring Exhibition (Super mixed reality activity using multimedia).

Also, through multi-source data integration the study will utilize:

1. Secondary Literature Analysis: This includes museum websites, how to develop an exhibition, news coverage about, and interviews with people involved;

2. Existing Academic Literature: References associated with research on experiences, immersion and digital technologies that are used in museums are included to help with situating both cases;

3. User Feedback Observation: This data comes from compiling public exhibition periods (by looking at visitor comments, social media feedback, attendance, and behaviour);

Although this research was conducted with a limited number of cases, most user experience data used was from existing secondary resources without the benefit of either onsite questionnaires or interviews. As a result, a lack of adequate project sample representativeness exists. Digital exhibition projects continue to be developed as technical specifications will not be available until after this research is completed, and future research will clearly identify a

relationship between "immersive experience" versus "understanding of culture". This should be accomplished using in-depth interviews, tracking user trajectories, and affective assessment technology.

5. Case study

Chapter two analyzes how users currently experience intangible cultural heritage exhibitions through the case study of the Xi'an Ming Qing Shadow Puppet Art Museum which has a traditional

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model emphasizing authentic artifacts displayed in a static fashion and how the Chengdu Museum national touring exhibition "Shadow Puppets in the World" uses commercially available digital immersive experience through multimodal XR interaction as an example of a model of modern exhibits. These two types of exhibits illustrate an analysis of the objectives and methods of interaction between users and between users and artifacts as well as the differences in interaction styles between the two exhibits.

5.1. Xi'an Ming-Qing Shadow Puppet Art Museum: authentic artifacts and static narratives

Xi'an Ming-Qing Shadow Puppet Art Museum showcases Shaanxi shadow puppetry from Ming and Qing dynasties. Exhibition strategy is built around "restoring the historical authenticity" through physical shadow puppets, scripts, puppet boxes, instruments and supplemented with text descriptions and fixed lighting. Because of this strategy, visitors can understand the integrity of the objects and their cultural richness, through examining their sculptural techniques and symbolic aesthetics.

Typically,visitors who engage with the display items do not engage with them interactively. Evidence suggests that while visitors generally describe their impression of the exhibition as being "exquisite" and "full of history," they were likewise aware of the shapes of the shadow puppets but did not understand how the shadows of the puppets were created. Empirical research supports these findings. Studies conducted on the display of items in traditional museums by Lu Lishu and Chen Qiaoyun at the Kaohsiung Shadow Puppet Museum found that a passive manner elicits a reception of little time spent on a display item, thus no retention of the cultural significance of the displayed object [11].

5.2. "Shadow Play in the World" national shadow puppet tour: digital immersion and user engagement

Compared to other travelling exhibitions, the Chengdu Museum's "Shadow Play in the World" exhibition is unique because it uses a variety of media, motion-sensing technology, and stories to create a multimodal cultural experience as visitors walk through the exhibition. The exhibition follows a narrative structure of "Life and Imagination in a Vast Universe" that is divided into sections containing the following chapters: "Traces of Shadow," "Continuous Shadow Play," "Behind the Shadow Window," "Endless Light and Shadow" [12]. In addition, the exhibition will show many different shadow puppet techniques and use elements of folk customs, seasonal celebrations, and music to create experiences for each chapter.

The exhibit features many opportunities for participation, primarily through interactive exhibits. Visitors can create their own virtual puppets by manipulating a "hand shadow interactive installation". In the last part of the exhibit, there will be a performance featuring a combination of animated puppetry and live action with an interactive element combining both digital and fine elements [13]. Here are many participatory opportunities, such as mini AR games and micro-script design that appeal to large numbers of youth and family visitors. More than 40,000 visitors attended the exhibit in only 5 days [14].

Research shows "low-barrier + high-feedback" interactive experiences enhance immersion and cultural receptivity. According to Liu & Sutunyarak, immersive technology has increased visitor behavioral intent and satisfaction [2]. Xu found out that augmented virtual museums increased visitor focus and efficiency while also preserving cultural depth [1]. Various studies have found that

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AR has increased visitor motivation to learn and explore, resulting in significantly higher knowledge retention rates.

The exhibit "Shadow Play in the World" used multimodal interactivity to employ XR applications and AIGC (Artificial Intelligence Generated Content) in producing exhibit content and user interaction. One example of this is that AI-generated voices create the lyrics and narration of the characters in a traditional shadow puppet show found at this booth. Users will be able to interact with traditional shadow puppets while hearing an AI-generated voice perform the lyrics in real-time to traditional singing, rather than requiring a live recording. This way, the installation is much easier to scale and offers the exhibit more flexibility for replicating it in different venues.

The project team used text generation models to mimic dialogue and create more extensive traditional play scripts. AI image synthesis techniques were used to simulate shadow puppetry, resulting in the creation of character performances in semi-automated play productions. AI-generated content within an XR interactive exhibition allows recreating traditional plays, and provides the potential to create personalised stories or storylines for the audience experience to assist in exhibition expansion.

Visitors stated that generating AIGC driven content enhanced the immersive nature of the experience as well as encouraging them to consider the boundary between "reality" and "imaginary." Some visitors who provided feedback noted that the AI voice of the shadow puppets felt "somewhat traditional yet extremely different" and provided them with an opportunity for both cultural exploration and cultural identity. This indicates that AIGC serves as more than just a creative tool but also as an avenue for "cultural regeneration" as it uses algorithms to create and promote diversity, continuity and collaborative activity in the creation of ICH.

5.3. Comparative analysis: conversion pathways between immersive approaches and cultural understanding

Traditional exhibitions have historically focused upon historical reconstruction and presentation of artifacts as priorities, with emphasis placed upon cultural authenticity. Conversely, digital exhibitions are focused upon scenarios and participatory experiences, thereby creating a focus on cultural tangibility. The Xi'an Ming-Qing Shadow Puppet Museum represents "visible history" while making "performable cultural spaces" through the presentation of "Shadow Play in the World."

Traditional exhibitions can provide a foundation of knowledge accumulation, but they do so without evoking a sense of emotional connection or engagement with the viewer. In comparison, digital exhibitions use various multi-sensory experiences (sound, movement and interactivity) to create an integrated cognitive, emotional and aesthetic experience of being immersed into the exhibition environment. The shift from being an "observer" to being a "participant" is related to current users' media habits and cognitive styles for conveying intangible cultural heritage.

6. Discussion

This paper looks at two exemplary exhibition cases, namely the Xi'an Ming-Qing Shadow Puppet Art Museum (Xi'an) and the Chengdu Museum's "Shadow Play in the World" traveling exhibition, to analyze how traditional static presentations and digital immersive experiences differ from one another in terms of the user experience. The results demonstrate that the multimodal nature of XR technologies has dramatically altered the perceptual logic and behavior of intangible cultural heritage exhibitions, resulting in users becoming inactive "viewers" to become active "participants".

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6.1. Enhanced immersion reshapes audience attention mechanisms

A museum of shadow puppet has the use of physical objects to display the art form and culture (cultural authenticity and artistic accuracy) so it can be helpful for a "deep learning" audience. The large amounts of audiences are dependent on being exposed to their culture before visiting and are not using either environmental stimulus or interactive support to be close to one another, therefore creating "cultural distance." "Shadow Play World" creates a multi-sensory immersive experience by using gesture control, interactive projections, soundscapes and animated shows that will successfully engage the easily distracted younger and family group audiences.

Immersive technologies improve visitor engagement. Xu found that immersive virtual recreation museums enhance visitor attention and encourage them to behave more actively during museum visits [1]. Research has also demonstrated that immersive experiences provide an increased sense of meaning for visitors, provide a greater sensory response from visitors, and provide a stronger sense of cultural presence to the visitors [9]. This was also true for the "Drama of Light and Shadow" exhibition in which light, sound, and interaction design were all used to capture the audience's attention.

6.2. Diversified participation pathways enhance cultural comprehension efficiency

Most exhibits are presented in a static format that is just "visible but not accessible", therefore guests will have only one way to receive knowledge. Digital displays enable guests to engage with exhibit content via low-threshold means such as AR or motion sensing, creating an experience chain of "physical engagement-sensory stimulation-knowledge construction." The example of one exhibit, "Shadow in the Human World", provides guests with the opportunity to perform as a puppeteer using a hand shadow performer by creating a simulated performance to help them better understand the logic and rhythm of their movements.

Research indicates narrative-based AR systems are associated with increased learner motivation and cultural literacy compared to non-narrative AR systems. They are also associated with higher emotional engagement and cognitive efficiency than other media [11]. Therefore, stories combined with an immersive interface create a more pre-active, exploratory, and perceptive user.

6.3. Emotional responses and cultural identification become core experience metrics

Traditional exhibition types offer detailed analysis and evidence of academics. One of the Xi'an Ming-Qing Shadow Puppet Museum's challenges is its use of amazing collections but frequently it has non-expert audiences "know the craft but not the context." Conversely, "Shadow Play in the World" allows visitors to experience shadow puppet plays digitally and creates the same festival atmosphere, creating an emotional connection between them and the memorable festival.

According to Liu and Sutunyarak, pleasurable feelings and flow-state of engagement are significantly related to users' cultural participation and future behavioral decisions. In some cases, the level of emotional engagement displayed in immersive experiences is more important than the reception of information [2]. The research also states that embedding immersive experiences in a cultural context typically facilitates the generation of a visitor's sense of belonging and the resonance of cultural identity [9].

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6.4. Transformation of exhibition logic and future pathways

Both of these cases show that traditional exhibitions stress "physical artifacts" as a means to establish authority over knowledge as well as authenticity about the piece itself while placing "user-centric" participation logic and immersive experiences at the forefront of digital exhibitions. These approaches are not strictly binary; they can work together or even combine multiple aspects of each other. Future "ideal" exhibitions are expected to maintain authenticity to artifacts, while adding multimodal sensory experiences along with technological means to achieve full cultural output through "knowledge + context + interaction."

Additionally, research shows that most current digital exhibitions are still mostly short-term endeavors with little long-term operation support and little or no user data collection, which affects their sustainability. The integration of the UTAUT2 and Immersion Theory models support the view that sustaining user participation with digital intangible cultural heritage will involve multiple issues and will require the simultaneous meeting of the user's immersion,social influence, and utility requirement [3]. The digital development of intangible cultural heritage must encompass both the technological aspect of intangible cultural heritage and the "post-experience follow-up" and "community co-creation" functions that allow users to remain involved in the dissemination of cultural knowledge beyond physical exhibits.

7. Conclusion

The rapid growth of digital technology and advancements in artificial intelligence (AI) and extended reality (XR) have transformed intangible cultural heritage by evolving from physical exhibits to immersive and multisensory experiences. This study will focus on how a performance-based, intangible heritage of shadow puppetry was exhibited at both the Xi'an Ming-Qing Shadow Puppetry Art Museum and the Chengdu Museum's "Shadow Play in the World" traveling XR exhibition. Specific aspects of user experience and emotional response as well as cultural dissemination through traditional and multimodal XR presentation will be compared.

The study suggests that multisensory XR increases user immersion and attention levels much more than current methods, while also creating more ways for users to interact with art. This enhances understanding and retention of cultural information. Digital experiences also create more emotion and cultural identity than other formats and enable those with no expertise to visually bond and identify with traditional cultural artifacts so they can share them with others. Lastly, the research indicates that there are long-term issues of sustainability related to the use of digital formats to preserve immaterial cultural heritage; these issues require future development of long-term operational systems to support aggregate user data collection and community collaboration systems.

Future digital exhibitions should emphasize education, tourism, and community-based dissemination to develop a more resilient and equitable cultural transmission system. Technology development and application must continue focusing on the need for cultural authenticity, narrative logic, and social responsibility. Therefore, multisensory XR experiences, used as tools for audience engagement, will serve as platforms for creating shared value and facilitating cultural understanding.

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