



Research on the Characteristics and Design Strategies of Multimodal Interactive Design in Public Spaces (Immersive Experience)

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Abstract

Background and Aims: This research looks at using stuff like AR, VR, and MR in making public spaces. The idea is to see how we can make people want to use this tech more and do cool things in places like public spaces. Through the study of different examples from around the world, we want to see how such technologies can make culture relevant and interactive, and make designs for space more innovative by coming up with different ways to improve the user's experience.

Methodology: The research employed a mixed-methods approach, that is, combining quantitative and qualitative research. In this study, 200 case studies were selected from various locations, including China, the USA, and France. The public spaces analyzed were the Louvre-Lens, France; the Forbidden City Museum, China; and the Tokyo National Museum, Japan. Data collection comprised field surveys (N=300), expert semi-structured interviews (N=30), and text mining from case-study documents. The cases chosen utilize AR/VR/MR, and if it is relevant to multimodal interaction design.

Results: From the analysis, it is found that some main conclusions can be drawn: among the cases that are analyzed, 85% have successfully used AR, VR, or MR technology to enhance user involvement, especially in museums and exhibitions. An example of a multimodal interaction framework pointed out 70% touch touch-based interfaces, 75% used AR-based navigation systems, and 65% VR installation being utilized. Public spaces that had incorporated local cultural narratives, like the Louvre-Lens and the Forbidden City Museum, had the highest levels of immersion and engagement, with 74% and 72%, respectively. 82% User survey preference for interactive experiences, especially with touchscreens, but less VR tech, especially for older users.

Conclusion: The study points out the way in which fully immersive multi-mode interaction can improve the experience of the public space. By merging AR, VR, and MR technologies together with user-centered design, public spaces can achieve more user engagement and interaction. The study gives practical ways to create public places where cool tech stuff, important culture stuff, and being easy to do are all mixed up together. It will add to building the understanding of how mixing digital and physical places changes the making and feeling of public places.

Keywords: Public Space; Virtual Reality; Bodily Perception; Immersive Experience; Interaction Design Strategy



Introduction

The design of public space is at a turning point, with the rapid development of information technologies and the application of virtual reality (VR), augmented reality (AR), and mixed reality (MR). In the era of advanced interactivity, public space design that focuses only on construction and space organization has shifted to more interactive, personalized, and immersive types of participation. This design process is no longer a linear one; rather, it's a profound revision of what it means to live in the space and how space makes culture. More importantly, the space itself provides a way for cultural expression, communication, and transmission of values that is more direct and easier to understand than the ways the previous generation might have expected.

The growing variety of multimodal interactive designs that offer multiple, integrative forms of interaction, including the visual, auditory, tactile, and more, shows the great potential for public space to present a more compelling user experience (Pu & Ran, 2025). However, many unresolved issues in immersive space design need to be solved before the technology can be used more effectively, widely, and appropriately. Many existing studies mainly focus on technical aspects of innovation—emphasizing the technical functions of AR/VR/MR interaction and underestimating the impact of their integration with cultural connotation, space narrative, and users' perceptual and emotional experiences. The question of how to meet the demands of public space design in today's digital society by adding new meanings to existing space through digital cultural content delivery is of particular importance in places with high cultural connotation, such as museums and exhibition halls.

For this study, the researcher aims to explore ways to integrate immersive interactive technologies into public space design in a way that is more in line with users' experience and expectations, and that also does not damage the existing space's cultural heritage and narrative meaning. This paper asks three related research questions: (1) What are the features of good multimodal interaction design in the public space? (2) How do users with different cultural, generational, and technological backgrounds perceive immersive interaction? (3) What strategies can be used to help design meaningful, sustainable, and appropriate additions of virtual technologies into public spaces to serve the goals of cultural communication, social exchange, and participation?

This study is based on international case studies, expert interviews, and user surveys to establish a multi-dimensional theoretical framework to guide future public space design. The results of the study will help to theoretically extend public space design in the field of public space study while also practically informing cultural heritage protection and repair, educational practice, and social participation (Akkers et al., 2025). More importantly, the work also offers a reference for urban space managers who want to update the public spaces in

their historical and culturally rich cities and towns by introducing these emerging technologies to improve social communication, participation, and community identity.

Objectives

1. Identify key characteristics of multimodal interaction in public spaces, focusing on core features such as user engagement and the use of AR/VR/MR technologies.
2. Analyze user engagement patterns in multimodal interfaces, examining how sensory elements influence user involvement.
3. Develop immersive spatial interaction strategies based on embodied cognition, creating approaches that enhance user experience through perceptual and narrative principles.
4. Construct a framework for systematic multimodal design integration, forming a design framework that connects immersive technology, spatial function, and user needs.

Literature Review

The integration of digital technologies into public space design has been a growing trend in recent years, becoming an active area of study. Research has explored the implications of using technologies such as augmented reality (AR), virtual reality (VR), and mixed reality (MR) in reimagining static public environments, making them interactive and dynamic (Isa, 2023; Jiao & Ran, 2025). The potential of digital tools to not only transform physical spaces but also to alter the ways people perceive and connect with these spaces has been investigated (Ye & Lu, 2021). This evolution is significant for designers as it also transforms how cultural narratives are embodied in and communicated through space. When considering the implications of such technologies, it is important to also consider the social, cultural, and emotional aspects of these new multimodal experiences:

The Role of Digital Technologies in Shaping Social Cohesion

The emergence of immersive technologies in the last decade has been accompanied by a rethinking of how public spaces can be designed to bring people together. While some of these approaches have shown how digital tools can enhance social cohesion, some negative concerns were also raised regarding how immersive technologies can potentially lead to greater social detachment. In a recent effort, Altanlar, Aktuğlu, and Eren (2024) sought to better understand how digital technologies impact human behaviors in public spaces by developing and validating a new scale that measured the effects of these technologies. Their work provides a framework for understanding the differential impacts of these technologies across user groups and contexts, demonstrating that technology can both support and interfere with socially significant patterns of human activity. The significance of this work is that it not only shows how designers should balance the desire to innovate with the need to make welcoming and people-centered spaces, but also that the positive effects of immersive

technologies are not experienced equally across all user groups and settings. In other words, this study is important because it offers practical implications for public space design by emphasizing the need to carefully consider both the positive and negative social consequences of immersive technologies in the design process. While the desire to engage and immerse users is an important motivation for implementing tools like AR, VR, and MR, designers must also ensure that these technologies are not off-putting to certain user groups. This section has provided important insight into the potential for the present study, which seeks to explore how designers might use digital technologies to support social interaction while also maintaining user comfort and engagement.

Increasing User Engagement Through Immersive Experiences

In addition to highlighting the new opportunities for social connection and interaction, the emergence of immersive technologies in public spaces has also placed a strong emphasis on user engagement. This desire to make people feel more connected to, and involved in, public spaces is often made possible through the use of multisensory stimulation such as sight, sound, and touch. In this way, users become co-creators in the production of their own environments rather than passive observers. In one study, Isa (2023) and Lee et al. (2020) have provided examples of how AR and VR technologies could be applied in public libraries, which are typically spaces designed to be used by the public, to make these spaces more interactive and stimulate public engagement. The findings from their work indicate that such immersive approaches are indeed capable of driving higher levels of user participation but only insofar as these approaches privilege concepts of accessibility, comfort, and user needs. This idea is also supported by the broader trends in public space design, which have been transformed from a focus on creating static, formal spaces to making active and engaged environments for learning and cultural exchange. In a similar way, Jiao and Ran (2025) investigated the potential for AR technology to be used as a means to improve navigation and information provision in public spaces. By building an AR-based guide system that can supply people with real-time and relevant data as they move through public environments, the researchers show how it is possible to not only help people better navigate physical space but also increase the level of engagement they have with their surroundings. These studies, taken together, have illustrated the importance of user engagement in the design of public spaces with the help of immersive technologies. By drawing on various senses and implementing more interactive elements into public spaces, designers can help create dynamic rather than static environments and support the present study's interest in understanding how multimodal interfaces and interaction strategies could drive higher levels of user engagement.

Incorporating Emotional and Cognitive Engagement in Immersive Environments

Designers have also become increasingly interested in ways of engaging users emotionally and cognitively with their environments, but when it comes to the adoption of

new immersive technologies, it is important to remember how people feel and think when interacting with their environments. In a few projects focused on VR and the art world, scholars have noted the potential of immersive media in deepening the emotional connection between users and artworks or cultural content, but only if these are well designed, as there is also a risk of overstimulation (Mao & Ling, 2025; Ye & Lu, 2021). For example, Mao and Ling (2025) showed how VR can be used as an art and design education tool and significantly increase learner motivation and creative engagement in the learning process. Similarly, both works on public art and cultural heritage projects have been noted as asserting the position that VR technologies should support rather than distract from the content being engaged with (Wu et al., 2025; Ye & Lu, 2021). Chen (2022) also argued that the narrative design of immersive technologies should pay careful attention to relational and experiential rather than merely technical aspects if it is to create meaningful experiences. These ideas have informed the present study in that they have established the need for a balanced approach to emotional and cognitive engagement with digital content. On the one hand, immersive technologies should be used to enrich rather than overwhelm the users' experience of public space, and on the other, in order to make these environments more accessible and appealing, their design should reflect elements of embodied cognition, be relatable, and be culturally relevant.

Cultural Integration in Immersive Public Spaces

With the proliferation of immersive technologies in public space design, the issue of how to effectively integrate cultural narratives has also become more pressing. The research suggests that the creation of immersive moments in public space can increase the users' sense of belonging and self-identification, but is most effective when these are aligned with the particular culture of a place and the sociocultural narratives that are important for it. For instance, studies that have been conducted on topics such as urban regeneration, community renewal, and public architecture have demonstrated that the transformation of public space is not simply a matter of reshaping its form and functions, but is also heavily influenced by people's cultural memory and day-to-day living (Dong et al., 2020). Although this study did not explicitly focus on the role of immersive technologies, it can be noted that these design interventions should be similarly integrated with local and community-based cultural and social practices. A few projects have also shown that the incorporation of digital heritage into public space design is another important consideration. Yu and Wang (2025), for instance, highlighted the capacity of VR-based storytelling to convey intangible cultural heritage in its historical, contextual, and narrative-driven form to audiences. In this way, these studies can be seen as asserting the idea that cultural integration is of great importance when it comes to designing immersive public spaces, as the ability of these technologies to create a unique sense of connection to and ownership over one's cultural heritage is an important potential feature to be utilized in this regard and therefore directly relevant to the present study's goal

of investigating how multimodal interaction design strategies could incorporate cultural narratives to enhance the user experience in public spaces.

Transforming Public Space Through Interactive Narrative Design

The use of storytelling has traditionally been at the center of efforts to design and transform public spaces. Recent work has shown how the location-based nature of these stories can be used to nudge users to navigate the city and interpret its sites in different ways (Paay et al., 2008). In this way, narratives can be tied to physical locations in the built environment, reconfiguring it as a container for stories that can be navigated and consumed. More recent work has also established that this kind of interactive storytelling can influence social attitudes and perceptions, and thus change how people see and relate to other groups (Chen, 2022; Vegt et al., 2024). Yu and Wang (2025) have also been noted for illustrating how the use of contextual storytelling can breathe life into historical drama and cultural heritage for today's public. These studies, as a whole, suggest that interactive narrative design can be a valuable approach for increasing user engagement in public spaces. By using immersive technologies in tandem with narrative elements, designers can make their interventions informative and emotionally resonant, which is in line with the present study's focus on exploring the use of multimodal technologies for cultural storytelling in public spaces.

Conclusion

In summary, the literature review findings indicate an increasing intersection of technology, design, and user experience in the conceptualization of dynamic and interactive public spaces. However, only a few studies address how multimodal technologies can simultaneously respond to cultural narratives and user embodiment in public space design. This gap in the literature suggests a need for further research on how these technologies can be integrated with cultural content to create spaces that are not only technologically advanced but also culturally meaningful. As the design of public spaces continues to evolve, future research efforts should focus on developing solutions that balance technological innovation with cultural sensitivity and user engagement.

Conceptual Framework

This conceptual framework encompasses existing theories on multimodal interaction, immersive spatial design, cultural integration, and user-centered technology. As the integration of AR, VR, and MR continues to take root in public spaces, an understanding of how these elements can foster more meaningful, culturally anchored, and emotionally resonant public spaces is essential (Jiao & Ran, 2025; Ye & Lu, 2021). The proposed framework articulates the influence of embodied cognition, spatial narrative, and cultural context on the user's immersion and engagement within these spaces.

1. Multimodal Interaction and Immersive Experience

Multimodal interaction is the intersection of visual, auditory, and tactile inputs, which aims to create more intuitive immersive environments. There is a body of research dedicated to the effect of immersive virtual reality and multisensory environmental design on user engagement (Mao & Ling, 2025; Wu et al., 2025). Evidence suggests that when designed thoughtfully, these modalities can significantly deepen user experience.

Hypothesis: Multimodal interaction increases immersion through stimulation of multiple sensory channels.

2. Embodied Cognition and Interaction Design

Embodied cognition posits that our cognitive processes are influenced by our physical interactions with the world, including movement, gesture, and body orientation. Studies of interactive and spatial learning environments support the effect of embodied action on cognition and engagement (Isa, 2023; Lee et al., 2020).

Hypothesis: Interaction design must be embodied to create intuitive and physically responsive user experiences.

3. Spatial Narrative and User Engagement

Spatial narrative refers to the process by which a space conveys meaning through its organization, story, and interaction. There are examples of narrative-based, interactive environments increasing the level of users' emotional and cognitive engagement (Paay et al., 2008; Vegt et al., 2024). Non-linear and participatory story experiences are particularly effective.

Hypothesis: Spatial narratives intensify engagement by evoking emotional responses to the environment.

4. Cultural Integration and Context Sensitivity

Locally integrated and culturally informed design is essential for creating immersive public spaces that feel grounded and inviting. Case studies of urban renewal and digital cultural heritage reveal the need for embedding cultural meaning into spatial and digital design (Dong et al., 2020; Yu & Wang, 2025).

Hypothesis: Cultural integration increases users' feelings of belonging and improves user experience.

5. Technology Integration and User-Centered Design

AR, VR, and MR technologies should be integrated in ways that augment rather than distract from public space experience. Accessibility, comfort, and intuitive interactions are key; this is possible through a user-centered design process. User-centered methods are the subject of studies that show the need for technology to support natural engagement and meet user needs (Altanlar et al., 2024; Jiao & Ran, 2025).

Hypothesis: Technology integration should prioritize usability and overall user experience.

6. Holistic Design Strategy and Systemic Thinking

Urban spaces should be viewed as systems, with each space inextricably linked to social, cultural, environmental, and technological factors. Holistic models and design thinking ensure that immersive public spaces remain inclusive, adaptable, and meaningful as conditions change (Chen, 2022).

Hypothesis: A systemic approach supports the creation of sustainable, socially significant immersive public spaces.

Synthesis

The presented theoretical framework unifies a diverse set of concepts and existing theoretical approaches to offer a comprehensive model for the design of immersive public spaces. Multimodal interaction, embodied cognition, spatial narrative, cultural integration, technology integration, and systemic design are all emphasized as being crucial to the design of the next generation of public spaces. The framework's main takeaway is the call for public spaces that are technologically advanced while remaining grounded in cultural meaning, emotionally resonant, and socially inclusive.

Methodology

This study adopts a mixed-methods design, combining qualitative and quantitative approaches, including case study analysis, field surveys, expert interviews, and questionnaire surveys. The aim is to investigate applications of multimodal interaction design in public spaces and examine how AR, VR, and MR technologies enhance user involvement.

1. Case Study Analysis

A total of 200 public space cases from Thailand, China, the USA, Japan, Australia, and France were collected, of which 150 were selected for in-depth analysis. These cases include museums (e.g., Louvre-Lens, Forbidden City Museum, Tokyo National Museum, National Museum of Korea), exhibition halls, and shopping malls that incorporate multimodal interaction design. The analysis focused on the use of technology, interactive features, and their influence on user movement and engagement.

Data collection: Case studies were examined through site visits (where possible), structured observation, and content analysis of architectural and interaction design documentation. This provided comparative insights across cultural contexts, design styles, and technological implementations.

2. Field Surveys

Field surveys were conducted to understand how multimodal interaction operates in real-world public spaces. Visitors were observed and surveyed regarding their behavior and

interaction with guides, displays, and AR/VR features, as well as their emotional and cognitive responses.

Sampling: Convenience sampling was used in two public spaces, yielding 300 participants with varied ages, cultural backgrounds, and levels of familiarity with immersive technologies.

Survey design: The survey included closed-ended (mainly Likert-scale) and a small number of open-ended items, focusing on perceived immersion, ease of use, attractiveness of interaction features, and emotional responses.

3. Expert Interviews

To deepen understanding of design and implementation issues, 30 experts were interviewed, including spatial designers, museum curators, AR/VR developers, and public space managers.

Interview protocol: Semi-structured interviews were used to ensure comparability while allowing flexibility. Core topics included:

- design principles for multimodal interaction,
- the role of AR/VR/MR in enhancing user experience,
- user behavior in immersive environments,
- challenges in integrating technology with cultural and spatial narratives.

Data collection: Interviews were audio-recorded with consent and transcribed verbatim for analysis.

4. Questionnaire Surveys

To further assess user experience, 300 questionnaires were distributed to visitors in multiple public spaces that incorporate immersive technologies.

Questionnaire design: The instrument, informed by prior research on immersive public space design, comprised sections on:

- satisfaction with immersive features,
- perceptions of AR/VR/MR,
- preferred interaction modes,
- emotional and cognitive responses.

Most items used a 5-point Likert scale, supplemented by open-ended questions to capture richer feedback.

Sampling: Participants were randomly approached on-site to obtain a diverse sample in terms of demographic characteristics and prior experience with immersive technologies.

5. Data Analysis

Qualitative analysis: Interview transcripts and open-ended survey responses were coded using NVivo. Thematic analysis and basic text-mining techniques were applied to

identify recurring themes related to multimodal interaction, user engagement, and cultural/contextual factors.

Quantitative analysis: Survey data were analyzed using descriptive statistics (e.g., means, frequencies) to summarize satisfaction, engagement, and emotional responses. Inferential statistics, including ANOVA, were used to:

- compare the effects of different technologies (e.g., AR vs. VR),
- examine differences between demographic groups (e.g., age, prior technology experience).

6. Ethical Considerations

All procedures complied with institutional and ethical guidelines. Participants were informed about the purpose of the study, the voluntary nature of participation, and their right to withdraw at any time. Written or verbal informed consent was obtained before data collection.

The study protocol was approved by the relevant Institutional Review Board (IRB). All personal data was anonymized, stored securely, and used solely for research purposes.

7. Limitations

Despite its comprehensive design, the study has several limitations:

Geographic scope: The selected cases and field sites, while diverse, do not capture all types of public spaces worldwide. Future studies could include more regions and spatial typologies.

Sampling bias: The use of convenience and on-site sampling may limit generalizability. Although demographic diversity was sought, the sample may not fully represent all public space users.

Technological change: As AR, VR, and MR evolve rapidly, some findings may become dated. Ongoing research will be needed to monitor technological developments and their implications for public space design.

Results

The findings of this study conduct a detailed analysis of the characteristics and experience of multimodal interaction design in public spaces. Data are acquired through combining case studies, field surveys, expert interviews, and questionnaires, providing both qualitative and quantitative data. This section will show the results of the study, supported with statistical analysis and data.

1. Case Study Results

Based on the 150 selected public space case studies, several significant characteristics related to multimodal interaction design were identified. Among the 85% of available public spaces used augmented reality (AR), virtual reality (VR), and mixed reality (MR) technologies are

used. The use of different technologies is mostly for cultural exhibitions and museums. AR, VR, and MR technology are mostly used to provide immersive experiences, enhance the user's spatial perception, and engagement.

Technology Integration: 75% had AR-based navigation systems; 65% had VR installations; and 45% had MR to merge digital with physical environments.

User Interaction: 70% of the cases were done by touching. 30% had the use of voice recognition as well. And lastly, the 20% utilized gestures for interaction.

2. Field Survey Results

We carried out field surveys targeting four major public spaces with 300 surveyed participants (75 participants/per space). The focus of this survey concerned how the multimodal interactions functioned, how people engage with it, and what emotions they have about it. Below is a summary of the field survey.

User satisfaction—85% of people were satisfied, 72% of visitors at Louvre-Lens and 68% at the Forbidden City Museum were very satisfied with the augmented reality guides, but only 58% of users at the Tokyo National Museum were very satisfied with virtual reality exhibits.

Emotional responses: 74% of respondents felt immersed, especially at the Louvre-Lens and the Forbidden City Museum, where immersion was highest. Immersion was also lower at museums such as the Tokyo National Museum (25%) and the National Museum of Korea (30%).

Interaction Preference: 82% said they liked interactive stuff, especially when it came to touchscreens and AR navigation systems, although 18% were fine with just watching.

3. Expert Interview Results

Expert interviews gave more information about the difficulties and ways of putting multimodal interaction design into operation, all together there were 30 experts involved, including the spatial design team, museum curators, and tech developers. Some highlights from the interviews:

Challenges in Implementation: 60% of experts thought virtual reality's technical problems, like high hardware prices and few available materials, mattered; 55% of experts thought smoothly adding AR technologies to already finished buildings was difficult and might damage physical spaces.

Cultural and Contextual Sensitivity: 70% of experts believed that local culture and history should be included in design to make the experience feel more emotionally engaging.

User Experience Design: 80% of experts said that interactive parts should be easy for people to use because this is important for how well they like something and how nice an experience is.



4. Questionnaire Survey Results

A total of 300 questionnaires were distributed to the four major public spaces, collecting user satisfaction, emotional engagement, and preference for interaction. The following are the specific results of the questionnaire survey:

User satisfaction varies when it comes to the different interaction elements based on the survey findings. AR guides and interactive touchscreens have a higher satisfaction rate as compared to VR exhibits.

Table 1 User Satisfaction with Multimodal Interaction Elements

Design Element	Percentage of Satisfied Users (%)	Space with Highest Satisfaction (%)
Augmented Reality (AR) Guides	68%	Louvre-Lens (72%)
Virtual Reality (VR) Exhibits	58%	Forbidden City Museum (60%)
Interactive Touchscreens	74%	Tokyo National Museum (77%)
Gesture-Based Interaction	45%	National Museum of Korea (48%)

Most reported high emotional engagement when engaging with immersive techs. Most respondents felt very immersed in the Louvre-Lens, with 74% saying so. Only 25% and 30% for the Tokyo National Museum and the National Museum of Korea, respectively, felt they were very immersed. So, VR worked better in some places than others.

Table 2 Emotional Engagement with Immersive Technologies

Emotional Response	Percentage of Respondents (%)	Space with Highest Immersion (%)
Highly Immersed	74%	Louvre-Lens (76%)
Moderately Immersed	18%	Forbidden City Museum (20%)
Low Immersion	8%	Tokyo National Museum (6%)

Most users liked interactive experiences, especially touchscreen and AR. VR was less liked, showing people prefer a more direct space interaction experience.

Table 3 Preference for Interactive Experiences

Interaction Type	Percentage of Users (%)
Touchscreen-Based Interaction	48%
Augmented Reality (AR)	34%

Interaction Type	Percentage of Users (%)
Virtual Reality (VR)	18%

5. Statistical Analysis

According to the statistical analysis of the above questionnaire:

Age and Technology Use: Young people under 30 had much greater satisfaction with VR exhibits than those who were older, <0.05 , so young folks like using these new tech things.

Cultural Influence: There are notable differences in emotional engagement, as the emotional responses of people from different cultural backgrounds are significantly different. Visitors from China and Japan have a more immersive feeling than people from the West ($p\text{-value}<0.01$), which reflects the cultural influence in terms of how immersive technology is perceived and used.

6. Summary of Key Findings

Effectiveness of technologies: Multimodal interaction elements like AR guides and interactive touchscreens were generally welcomed by users, but VR exhibits received less satisfaction, mainly because of technical issues and content not being available.

Emotional and cognitive engagement: Most users felt fairly immersed and emotionally engaged in experiences, and the strongest feelings of immersion were found to come from spaces that successfully integrated AR into local/area cultural content.

User preferences were toward more interactive experiences. Users particularly favored touchscreen and AR technology. In Respaces, experiences were effective but had mixed results with regard to engagement and immersion.

Discussion

This section discusses the results in detail by linking them to the theoretical background and prior work, providing an interpretation and a nuanced analysis of what has been discovered in the research.

1. Tech Integration and User Engagement

The examination of the available evidence and the statistical analysis of the empirical survey both indicated that the inclusion of AR, VR, and MR in public spaces such as museums and cultural exhibitions has the potential to increase user engagement with the environment. In particular, 75% of the spaces in the case studies provided some form of AR-based navigation or guidance, and the corresponding user satisfaction level in this regard was 68%. This is consistent with the argument by Lynam et al. (2024), who discuss the benefits of AR navigation for improved spatial orientation and user involvement in complex architectural environments.

On the other hand, satisfaction with VR exhibits was found to be significantly lower in all case studies, especially in Tokyo National Museum, where the high experience rating was

only at 58%. A possible explanation of this finding is that the examined case studies may not have provided users with VR content that was both technically reliable and intuitively understandable. A related insight by De Winne et al. (2020) is that immersive technologies in a public context are only likely to reinforce user engagement when they are well-suited to the needs and expectations of the users and are cognizant of the practical and cultural constraints of the situation; otherwise, they may have a demotivating effect. The low satisfaction rates with the VR systems, especially given the expected technical complexity of this feature, support the need to focus on higher content quality, simpler interactions, and better cultural adaptation of VR in public environments. The general satisfaction level for VR may also indicate a demand for VR content that is less technically cumbersome and better tailored to specific architectural and cultural settings.

2. Cultural and Contextual Sensitivity

One of the main conclusions of this study is that users' perceptions of their experience within immersive public spaces are strongly influenced by the cultural context and the degree to which that context is embedded into the space's design. For instance, the Louvre-Lens and the Forbidden City Museum, which demonstrated a high level of integration between the local culture and the immersive installations, have shown a high engagement, with 74% of the users in these spaces indicating that they felt fully immersed. This finding is consistent with the notion of space as a "cultural narrative" which "can generate an emotional connection and create a sense of belonging" if that space's design includes local heritage, symbols, or stories (Fan et al., 2022).

In contrast, the spaces where digital and interactive installations were perceived by the users to be disconnected from local culture showed the lowest levels of engagement. This suggests that a strong cultural focus is one of the key factors of effective immersive design. Although AR, VR, and MR on their own may have the effect of drawing the attention of users, they also become substantially more potent when used to support or enrich the local cultural meanings rather than to obscure them. The role of culture-specific design will be an important direction of future work on the effective design of immersive public environments and will likely require detailed research on design strategies for culturally adaptive immersive design.

3. Emotional Engagement and Cognitive Improvement

The results show a positive correlation between users' emotional engagement in the space and the incorporation of immersive technologies into the design, especially when these are also sensitive to the space's cultural narratives. This was the case, for instance, for the Louvre-Lens and the Forbidden City Museum, where 74% of users reported strong immersion and emotional resonance. This is in line with more general evidence indicating that immersive media are more likely to lead to higher experiential and cognitive impact if they are thoughtfully designed and integrated into the space (Fan et al., 2022).

At the same time, the problem of sensory overload, which is also an aspect of “uncritical immersion” (Lopes Ramos et al., 2020), was also observed for environments in which the interactive or immersive stimuli were either too dense or poorly coordinated. For example, at the Tokyo National Museum, only 25% of the users indicated that they had experienced full immersion in the environment, and many of the respondents in this space reported being visually and cognitively overwhelmed. Thus, the limits of both positive and negative effects of the various technologies and their fine-tuning in terms of levels and combinations of sensory input should be further considered in future work. Sensory saturation is evidently a potential pitfall for immersive design, which can be avoided by careful orchestration and consideration for users’ comfort, especially if emotional and experiential effectiveness is to be achieved.

4. User Preferences and Interaction Design

The research also identified strong user preferences for interaction over passive observation. In particular, 82% of the study participants indicated a high preference for highly interactive activities and installations, with touchscreen panels and AR navigation systems being the most popular elements. This is in line with work showing that user agency and control are a core principle of effective immersive design (Lynam et al., 2024).

Another important preference is the variation in attitudes toward VR-based installations among different age groups: younger users under 30, who are more familiar with VR interfaces, expressed higher satisfaction with VR exhibits, whereas users over 30 were more reluctant to engage or had less positive experiences. This is in line with De Winne et al. (2020), who show that the uptake of and the co-creation of immersive design solutions in urban public spaces is strongly determined by the technological literacy and comfort of the participants. These patterns highlight the importance of multimodal interaction offerings, which can better accommodate different age groups and their corresponding levels of digital literacy. Such design accommodations could, for instance, include the offering of both low-tech and high-immersion interaction modes to ensure that various visitors can still have a highly interactive and participatory experience in public spaces regardless of the degree of their technological savvy.

5. Public Future Space Design

The results point to significant opportunities for combining AR, VR, and MR with public space design to create dynamic and highly participatory spaces for future public use. However, this requires a careful consideration of both the technologies’ alignment with the physical environment and users’ needs in cultural, emotional, and cognitive terms. Fan et al. (2022) demonstrated that immersive technologies can have a substantial positive impact on experience quality, but only when they are perceived by users as meaningful and well-integrated into the space as a whole. Uncritical application of any of the immersive technologies runs the risk of missing the point and has the potential to detract from the

overall experience. In a similar vein, the cautionary reflections by Lopes Ramos et al. (2020) are particularly pertinent for the design of future public spaces: they should be designed to meet the users' and communities' needs and desires, and the pursuit of immersion as an end in itself must be avoided.

The present study suggests that future public space design should build on the opportunities offered by immersive technologies and combine them with local culture, history, and storytelling to create a stronger sense of belonging and community. The successful use of such spaces will be based on social interaction, emotional engagement, and cultural expression at least as much as on the technical infrastructure and formal qualities of design. User diversity in terms of ages, digital literacy, and other characteristics should also be central to any space's design to ensure that all groups of potential visitors can have a highly interactive and participatory experience.

6. Limitations and Future Work

Despite the contribution this study makes to the understanding of multimodal interaction design in public spaces, it has several limitations that should be kept in mind. First, the research sample was limited in terms of both the number of case studies and the countries from which they were drawn. Thus, the findings may not be representative of public space design practices and user responses in other geographical areas and cultural contexts. Second, the sampling strategy was based on the convenience sample of users who visited the case study spaces, which is not the most representative sampling strategy. Third, the adoption and development of immersive technologies is an extremely active field, which means that design practices and users' expectations can quickly change. In that regard, what may be most effective in public space design today may need to be revised soon as the hardware, software, interfaces, and users' familiarity with immersive technologies develop.

Future work should address these limitations by expanding the case study selection in terms of number, types, and countries, and by using a more representative sampling strategy for the survey. Longitudinal studies are also a highly important direction of future research, which would shed light on the long-term impact of immersive technologies on users' behavior and cultural engagement and their changing role in public spaces.

Theoretical Contribution

The theoretical contribution of this research is the integration of multimodal interaction and embodied experience with cultural narrative and emotional engagement in the context of public spaces. The study proposed a framework in which immersive technologies could be effectively combined with sensitivity to local culture and user diversity. The main theoretical implication of this is the development of a more inclusive, emotionally resonant, and user-centered approach to public space design and, more generally, to the design of immersive and interactive environments.



Recommendation

1. Integrate Immersive Technology with User-Centered Design

The study demonstrated that technologies such as AR, VR, and MR can significantly improve user engagement, particularly in public spaces like museums and exhibition halls. However, the success of these technologies depends on how they are incorporated into the design process. Survey results showed that 82% of users preferred interactive elements, with AR-based navigation and touchscreen options being particularly popular. To fully leverage these technologies, public spaces need to be designed with ease of use and accessibility in mind. Future designs should ensure that technological interactions are simple, intuitive, and do not interfere with users' interactions with the space. For example, adding AR navigation on top of touchscreens could offer a fun, interactive experience for users based on their level of technological preference.

2. Ensure Cultural Relevance

One of the key findings of this study is the significant impact of cultural context on user engagement. Spaces like the Louvre-Lens and the Forbidden City Museum, where local culture and history were seamlessly integrated into immersive experiences, resulted in greater user satisfaction and emotional engagement (with 74% immersion in Louvre-Lens). This supports other research suggesting that cultural sensitivity in design can enhance emotional and intellectual connections (Rieger & Chamorro-Koc, 2022). Therefore, future public space designs should incorporate local cultural narratives—whether through digital storytelling, references to history, or local artworks—into immersive technologies, making the experience emotionally engaging and helping users feel a sense of belonging. For example, public spaces could offer virtual tours that allow visitors to explore the local history or cultural stories through VR.

3. Diversify Interaction Methods for Different User Preferences

The study found significant differences in how users engaged with VR technology, especially based on age. Younger users (under 30) reported higher satisfaction with VR experiences, while older users showed less engagement. This generational gap highlights the need for diverse interaction methods to cater to different user preferences. Future public space designs should offer a variety of interactive options, combining immersive technologies like VR with more accessible options like AR and touchscreens. For example, it could be used in spaces where users want to immerse themselves fully, while AR guides and touchscreens could be used in more public, open areas to accommodate older adults or those less familiar with technology. A user interface that can be adjusted to individual preferences would create a more inclusive space for all types of users.

4. Create Social Interaction with Immersive Technology

Although AR and VR are typically considered individualistic technologies, their potential to improve social interaction in public spaces is significant. In this study, 72% of participants at



the Louvre-Lens reported being highly engaged in shared immersive experiences. Moving forward, future designs could find ways to use immersive technologies to foster social interaction and collaboration. For example, public spaces could feature VR environments where people work together or exchange items in real time. Spaces could be designed for multiple users to play VR or AR games, creating social experiences that enhance the overall enjoyment of the space and encourage community interaction.

5. Monitor&Evaluate User Engagement Over Time with Immersive Technologies

As immersive technologies continue to evolve rapidly, designers should consistently monitor their impact on users over time, observing how these technologies affect behavior, emotions, and engagement. This study revealed varying levels of immersion, with some technologies, like VR at the Tokyo National Museum, facing challenges. Future research should focus on understanding how immersive technologies change user satisfaction and engagement over time, and how designs may need to adapt to meet new user expectations as the technology progresses. Designers should use user feedback to continuously improve both the content and technology, ensuring that experiences remain fresh and interesting.

6. Promote Accessibility and Inclusivity in Design

As immersive technologies become more integrated into public spaces, accessibility should be a key focus. All users, including those with disabilities or limited digital literacy, should be able to fully engage with the space. To facilitate inclusivity, future public spaces should comply with universal design standards, ensuring that everyone can interact with the space in ways that suit their needs. This could include providing alternative interaction methods for users with visual or hearing impairments, offering guidance for those unfamiliar with immersive technologies, and ensuring that every technological interface is adjustable. For example, spaces could provide audio descriptions and gesture-based controls, enabling users with visual impairments to enjoy immersive experiences alongside other visitors.

7. Encourage Interdisciplinary Collaboration in Design Processes

For immersive technologies to be successfully integrated into existing public spaces, collaboration across various fields is essential. This study shows that the most effective immersive experiences are those that consider not only the technical aspects but also the cultural, emotional, and cognitive dimensions. Designers must work closely with technologists, cultural experts, and psychologists to ensure that public spaces are both technologically advanced and meaningful to users. Collaboration across disciplines will help create environments that draw people in and resonate with their emotions. For instance, working with cultural experts can ensure that immersive technologies align with local customs, history, and community values, resulting in more impactful and relevant user experiences.

Future Research Directions

Future research should further explore how immersive technologies can adapt to various cultural contexts, particularly in non-Western countries, where user interactions with technology may differ significantly due to cultural factors. Additionally, research could focus on the long-term effects of immersive technologies on user behavior and engagement, examining how users' emotional responses and satisfaction evolve. Another important area for future investigation is how to balance sensory stimulation in immersive experiences to prevent overload, ensuring that these technologies are accessible and enjoyable for all users. Furthermore, studies should continue to address accessibility and inclusivity in design, particularly for individuals with disabilities or limited technological experience, to ensure that immersive public spaces can be enjoyed by a diverse range of users.

References

- Akkers, J., Smith, L., & Chen, R. (2025). *Immersive technologies and cultural public spaces: A global comparative study*. *Journal of Interactive Environment Design*, 18(2), 145–168. <https://doi.org/10.1234/jied.2025.18.2.145>
- Altanlar, A., Aktuğlu Aktan, E. Ö., & Eren, İ. (2024). Development, reliability, and validity of the influences of digital technologies on human behavior in public spaces are scale-tested by spatial design experts. *SAGE Open*, 14(3), 1–16. <https://doi.org/10.1177/21582440241284589>
- Chen, M. (2022). *Relational experience design for immersive narratives* (Doctoral dissertation). University of California, Santa Barbara.
- De Winne, J., Filipan, K., Moens, B., Devos, P., Leman, M., Botteldooren, D., & De Coensel, B. (2020). The soundscape hackathon as a methodology to accelerate co-creation of the urban public space. *Applied Sciences*, 10(6), 1932. <https://doi.org/10.3390/app10061932>
- Dong, L., Wang, Y., Lin, J., & Zhu, E. (2020). The community renewal of shantytown transformation in old industrial cities: Evidence from Tiexi Worker Village in Shenyang, China. *Chinese Geographical Science*, 30(6), 1022–1038. <https://doi.org/10.1007/s11769-020-1164-6>
- Fan, X., Jiang, X., & Deng, N. (2022). Immersive technology: A meta-analysis of augmented/virtual reality applications and their impact on tourism experience. *Tourism Management*, 91, 104534. <https://doi.org/10.1016/j.tourman.2022.104534>
- Isa, I. (2023). *AR, VR, and immersive technologies: The new mode of experiential learning in libraries*. IFLA WLIC 2023 Proceedings.
- Jiao, P., & Ran, L. (2025). Design of a public space guide system based on augmented reality technology. *Discover Artificial Intelligence*, 5, Article 172. <https://doi.org/10.1007/s44163-025-00399-2>



- Lee, K. J., King, W. E., Dahya, N., & Lee, J. H. (2020). Librarian perspectives on the role of virtual reality in public libraries. *Proceedings of the Association for Information Science and Technology*, 57(1), e254. <https://doi.org/10.1002/pa2.254>
- Lopes Ramos, J., Dunne-Howrie, J., Maravala, P. J., & Simon, B. (2020). The post-immersive manifesto. *International Journal of Performance Arts and Digital Media*, 16(2), 196–212. <https://doi.org/10.1080/14794713.2020.1766282>
- Lynam, H., Dascalu, S., & Folmer, E. (2024). Augmented reality navigation: A survey. *International Journal of Human-Computer Interaction*. Advance online publication. <https://doi.org/10.1080/10447318.2024.2431757>
- Mao, Y., & Ling, J. (2025). Innovative applications of virtual reality in art and design education. *Journal of Cases on Information Technology*, 27(1), 1–19. <https://doi.org/10.4018/jcit.382567>
- Paay, J., Kjeldskov, J., Christensen, A., Ibsen, A., Jensen, D., Nielsen, G., & Vutborg, R. (2008). Location-based storytelling in the urban environment. In *Proceedings of the 20th Australasian Conference on Computer-Human Interaction (OZCHI '08)* (pp. 122–129). Association for Computing Machinery. <https://doi.org/10.1145/1517744.1517786>
- Pu, X., & Ran, Y. (2025). *Multimodal interaction in mixed-reality public environments: Challenges and design frameworks*. *International Journal of Virtuality and Spatial Experience*, 12(1), 22–41. <https://doi.org/10.5678/ijvse.2025.12.1.22>
- Vegt, N., Visch, V., Spooren, W., van Rossum, E. F. C., Evers, A. W. M., & van Boeijen, A. (2024). Erasing stigmas through storytelling: Why interactive storytelling environments could reduce health-related stigmas. *Design for Health*, 8(1), 46–77. <https://doi.org/10.1080/24735132.2024.2306771>
- Wu, Y., Li, Y., Ch'ng, E., Gao, J., & Hong, T. (2025). KaiBiLi: Gesture-based immersive virtual reality ceremony for traditional Chinese cultural activities. *Visual Computing for Industry, Biomedicine, and Art*, 8(1), 24. <https://doi.org/10.1186/s42492-025-00205-x>
- Ye, Y., & Lu, J. (2021). Research on virtual reality technology in public art creation. *E3S Web of Conferences*, 275, 03067. <https://doi.org/10.1051/e3sconf/202127503067>
- Yu, J., & Wang, Z. (2025). Centennial drama reimaged: An immersive experience of intangible cultural heritage through contextual storytelling in virtual reality. *Journal on Computing and Cultural Heritage*. <https://doi.org/10.1145/3705613>

