

Beyond usability: A user-centered evaluation framework for augmented reality experiences in cultural heritage

Sophia Bakogianni

Department of Communication, Media and Culture, Panteion University of Social and Political Sciences, 136, Syngrou Av., Athens, 17671, Greece

ARTICLE INFO

Keywords:

Augmented reality
User experience
Cultural heritage
Immersive experiences
Evaluation framework
Digital museology
Visitor studies

ABSTRACT

Augmented Reality (AR) is increasingly deployed in museums, heritage sites, and public spaces, yet its evaluation remains dominated by system-centered approaches that treat usability, immersion, and impact metrics as success measures. This paper proposes a user-centered conceptual evaluation framework for AR experiences in cultural heritage, articulated through six experiential dimensions: *practices, perceptions, feelings, sociality, immersion and presence*, and *usability*, repositioning the latter two alongside dimensions largely overlooked by existing approaches. The framework is grounded in an exploratory, small-scale case study of the location-based AR exhibition *Seeing the Invisible* in the National Garden of Athens, using a mixed-methods design combining online surveys and semi-structured interviews. Findings show that spatial navigation, social interaction, and the physical landscape were at least as significant as technological features. The framework illustrates how the six dimensions can guide evaluation design and analysis in situated AR heritage encounters, offering a conceptual resource for future AR heritage projects.

1. Introduction

Augmented Reality (AR) technologies have become increasingly prominent in cultural heritage contexts, including museums, exhibitions, historic sites, and public urban spaces. AR enables the overlay of digital content onto physical environments, offering potential for layered interpretation, visualization, and engagement with cultural narratives that complement traditional presentation methods (Devine and Tarr, 2019; Gao et al., 2022). Recent reviews of AR in cultural heritage highlight a growing diversity of applications, ranging from learning and tourism to narrative reconstructions and gamified experiences (Chatsiopoulou and Michailidis, 2025).

As AR applications proliferate, the question of how to evaluate user experience in cultural heritage environments has become increasingly pressing. Existing evaluation approaches, largely derived from Human-Computer Interaction (HCI), usability research, and immersive media studies, have developed robust instruments for measuring system performance, usability, immersion, presence, and affective response. Standardized measures such as the System Usability Scale (SUS) (Brooke, 1996), User Experience Questionnaire (UEQ) (Laugwitz et al., 2008; Schrepp et al., 2017a, 2017b), and presence scales (Grassini and Laumann, 2020) have been widely adopted to benchmark comparative

performance and to support generalizable claims about system quality and user response. These tools are valuable for comparing applications, but they were largely developed for digital interfaces and controlled immersive environments, not for situated AR encounters in tangible heritage settings (Moinnereau et al., 2022).

In digital museology and heritage studies, evaluations of AR applications often replicate these constructs, such as usability, satisfaction, and engagement, as part of mixed-methods designs that include interviews or observational data, yet the conceptualization of experience remains anchored in UX and system performance logics. Systematic reviews of AR in cultural heritage note that while user experience is frequently discussed, methodological approaches to evaluation vary widely and few studies probe the deeper dimensions of AR use, interpretation, and meaning-making (Chatsiopoulou and Michailidis, 2025). These patterns suggest that existing approaches produce only a partial account of how AR is experienced in heritage settings.

The difficulty is not simply one of coverage. It reflects a deeper epistemological orientation shared across HCI, immersive media, and much heritage AR evaluation, in which experience is conceptualized primarily as a response to technological affordances or system design. This orientation installs usability as the endpoint of evaluative concern, not as an enabling condition among several, marginalizes the social,

This article is part of a special issue entitled: XR Heritage: Design and Engagement published in Digital Applications in Archaeology and Cultural Heritage.

E-mail address: sophia.bakogianni@gmail.com.

<https://doi.org/10.1016/j.daach.2026.e00598>

Received 2 March 2026; Received in revised form 1 September 2026; Accepted 5 October 2026

Available online 6 October 2026

2212-0548/© 2026 The Author. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Open access publication of this article was funded by HEAL-Link under an agreement between Elsevier and HEAL-Link

spatial, and interpretive dimensions through which visitors negotiate AR encounters, and assumes conditions of use that do not apply to AR in open, publicly situated heritage environments. A framework that starts from what visitors do, feel, interpret, and share with others in a culturally situated encounter is therefore needed.

To address this gap, this paper proposes a user-centered conceptual evaluation framework specifically tailored to AR experiences in cultural heritage contexts. The framework does not reject existing UX and immersive constructs but reconfigures them to foreground lived experience, spatial context, and visitor agency. It is grounded in a case study of the location-based AR exhibition *Seeing the Invisible* in the National Garden of Athens, treated not as a representative sample of AR heritage applications, but as a specific, situated instance through which to develop and illustrate the framework. The aims are threefold: (1) to analyze how visitors experienced a situated AR art exhibition across behavioral, perceptual, affective, and social dimensions; (2) to consolidate these insights into a user-centered conceptual evaluation framework that foregrounds visitors' experience in context, attending to cultural meaning and visitor agency; and (3) to show how this framework can inform AR heritage evaluation and contribute to analytical practice in digital museology, offering an experience-oriented alternative to existing system-centered approaches. The framework is presented as a conceptual contribution grounded in one case, requiring further empirical application across different AR heritage contexts.

2. Related work

Research on AR evaluation has been strongly influenced by Human-Computer Interaction (HCI) and usability studies. Much of this work measures task performance, system responsiveness, and ease of interaction, using instruments such as the System Usability Scale (Brooke, 1996; Lewis, 2018), the Technology Acceptance Model (Davis, 1989), the User Experience Questionnaire (Laugwitz et al., 2008; Schrepp et al., 2017a, 2017b), and related UX scales (Siang et al., 2019), which have been widely adopted in heritage AR studies precisely because they are robust, scalable, and comparable across contexts (Szekely et al., 2023; Wang, F. et al., 2025). Their value for benchmarking technical performance is genuine. These instruments, however, were developed for controlled digital interface settings, not for the hybrid, spatially embedded encounters that characterize AR in real-world heritage environments. When usability becomes the primary criterion of evaluative success, it renders invisible what visitors do with their bodies, devices, and companions as they move through a landscape, what they make of the artworks or content they encounter, what they feel, and whether the experience carries cultural meaning. This is not a measurement gap that better scales would close. It reflects a deeper choice about what counts as a successful heritage AR encounter.

Immersive media research has shaped AR evaluation through the concept of presence, understood as the subjective 'sense of being there' in a mediated environment (Slater, 2009). Presence has been operationalized through validated questionnaires (Grassini and Laumann, 2020; Witmer and Singer, 1998; Witmer et al., 2005), and a substantial body of research suggests that higher levels of technological immersion produce stronger feelings of presence (Cummings and Bailenson, 2016). Presence is widely understood to amplify engagement and affective response, making it a central evaluative target in immersive media design (Lombard and Ditton, 1997). Industry and research evaluation frameworks have drawn on these constructs by combining presence with affective scales, memorability indicators, and cultural impact metrics, though primarily in lab-based VR contexts, not open, situated heritage environments (Lessiter et al., 2018; Wang, N. et al., 2025). Yet presence as a construct was developed overwhelmingly in the context of head-mounted VR in controlled settings, where physical surroundings are occluded and the user's perceptual field is largely determined by the system. When exported to AR in open, outdoor, socially populated heritage environments, its foundational

assumptions fail in instructive ways. In AR, the physical environment is not occluded but continuously co-present, shaping what digital content means and how it is perceived. The visitor is already in a real place, and digital content must make sense within it. Presence is not a unitary state achieved by the system, but a fluctuating quality co-produced by artworks, spatial anchoring, device handling, and companionship. Sharing a screen, navigating toward a geo-specific pin, or pausing with a companion to discuss what a digital artwork evokes are not conditions surrounding the experience but core elements of what the experience is.

Within museum and heritage studies, AR has been explored as interpretive technology that can complement physical collections, enhance storytelling, and support embodied forms of engagement. Evaluative studies in this domain often examine learning outcomes, engagement levels, or visitor satisfaction, sometimes combining observational methods with questionnaires or interviews (Chatsiopoulou and Michailidis, 2025). Yet even here, many evaluations adopt metrics and constructs imported from usability or immersive media research without critically examining their suitability for cultural contexts, frequently reducing experience to satisfaction scores or perceived effectiveness (Kleftodimos et al., 2023; Koo et al., 2019; Shi et al., 2023). Proposals to address this have remained within a system-centered logic, conceptualizing experience primarily in terms of UX and engagement factors such as aesthetics, novelty, and interactivity, leaving the situated cultural dimensions of the encounter unaddressed (Ramtohl and Khedo, 2021).

Museum and heritage visitor studies offer a different point of departure. Influential scholarship understands the museum visit as shaped by the interplay of personal, sociocultural, and physical contexts, treating visitor agency, interpretation, and social interaction as constitutive dimensions of experience (Falk and Dierking, 2013; Pekarik et al., 1999; Roppola, 2012). Subsequent work in this tradition has extended attention to the behavioral dimensions of this engagement, examining how visitors interact with exhibits over the course of a visit (Schreiber et al., 2013). These insights have not been carried into AR evaluation frameworks, which continue to conceptualize experience primarily as a response to technological affordances, leaving the embodied, social, and interpretive dimensions of cultural encounter systematically unaddressed. In AR encounters in open, publicly situated heritage environments, where visitors navigate physical space, share devices, discuss what they see, and negotiate the relationship between digital content and place, these dimensions are not peripheral to the experience but central to it.

This gap requires an evaluative starting point that treats practices, sociality, and interpretation as primary concerns, engages with the affective and spatial dimensions of cultural encounter with the same rigor as technical performance, and positions usability as a background condition, not the primary measure of success. The user-centered conceptual evaluation framework proposed in Section 3 responds to this need by foregrounding *practices, perceptions, feelings, sociality, immersion and presence*, and *usability* as interrelated dimensions of situated cultural AR encounters.

3. Conceptual framework: A user-centered approach to evaluating AR experiences

This section presents the user-centered conceptual evaluation framework that structures the study. Building on museum experience research, cultural communication, and immersive media studies, the framework shifts attention from system performance to visitors' lived experience of AR as a cultural encounter (Economou et al., 2019; Falk and Dierking, 1992, 2013; Pekarik et al., 1999; Roppola, 2012). It proposes that AR experience in cultural heritage settings is best understood as a situated, multidimensional, and socially embedded process, and that evaluation must be oriented toward what visitors experience in context.

3.1. Reframing evaluation from systems to experience

This paper adopts a user-centered, experience-oriented perspective on AR evaluation, conceptualizing experience as a situated and relational process shaped by interactions between users, digital content, physical space, social context, and institutional framing. From museum and heritage studies, this view resonates with models that describe visitor experience as emerging from the interplay of personal, socio-cultural, and physical contexts (Falk and Dierking, 1992, 2013; Roppola, 2012). In immersive media research, a recent scoping review likewise calls for evaluation approaches that foreground what matters to users in context, instead of relying primarily on system-driven constructs and ad hoc combinations of metrics (Li et al., 2026).

The framework proposed here starts from the premise that cultural AR experiences are not merely technological encounters. They are cultural events that unfold within specific places, narratives, and social situations, and are interpreted by users drawing on prior knowledge, expectations, emotions, and relationships with others. As such, evaluation must attend not only to how well a system functions, but to how it is experienced, interpreted, and appropriated by users in context. This shift entails an epistemological repositioning, moving from system-centered measurement toward an interpretive understanding of experience, and from isolated user responses toward an examination of lived, embodied, and socially situated engagement.

3.2. Experiential dimensions of AR user experience

The framework adapts and extends a multidimensional approach originally developed in the author's previous research on museum social media experiences, where behavioral, perceptual, and affective dimensions were combined to analyze users' communicative practices and responses (Bakogianni, 2022). It draws further on research in museum experience, immersive media evaluation, and cultural communication

(Economou et al., 2019; Lessiter et al., 2018; Moynereau et al., 2022).

The six dimensions were selected in direct response to the evaluative gaps identified in Section 2. *Usability* is retained from HCI research but repositioned as a condition that shapes access to the experience, not the primary success criterion, on the grounds that adequate technical performance is necessary but not sufficient for a meaningful cultural AR encounter. *Practices* foreground what visitors do with their bodies, devices, and companions as the primary behavioral unit of evaluative concern, drawing on practice theory to situate AR engagement within socially organized, embodied action. *Immersion and presence* are retained from immersive media research but reframed as one quality of spatial engagement among several that evaluation should attend to, acknowledging that in AR the physical environment remains visible and meaningful, shaping how digital content is perceived. *Perceptions, feelings*, and *sociality* address the interpretive, affective, and social dimensions that neither HCI nor presence research capture, drawing on museum and heritage visitor studies to treat them as primary evaluative concerns. The framework's contribution lies in this reconfiguration, that is, in the reordering of evaluative priorities relative to existing AR evaluation approaches, the specification of relational connections among dimensions, and the grounding of the whole in a user-centered account of situated cultural encounter, not system performance. The dimensions form a structured set of relationships, illustrated in Fig. 1. These relationships are proposed on conceptual grounds. They are not tested as causal effects in this study. The framework positions usability as an enabling condition for practices. Practices connect to immersion and presence, to sociality, and to feelings. Immersion and presence, sociality, and feelings each relate to perceptions, which the framework treats as the interpretive layer through which the overall experience is judged and remembered.

The six dimensions that constitute this relational structure are defined below, each specified in terms of its distinctive evaluative focus

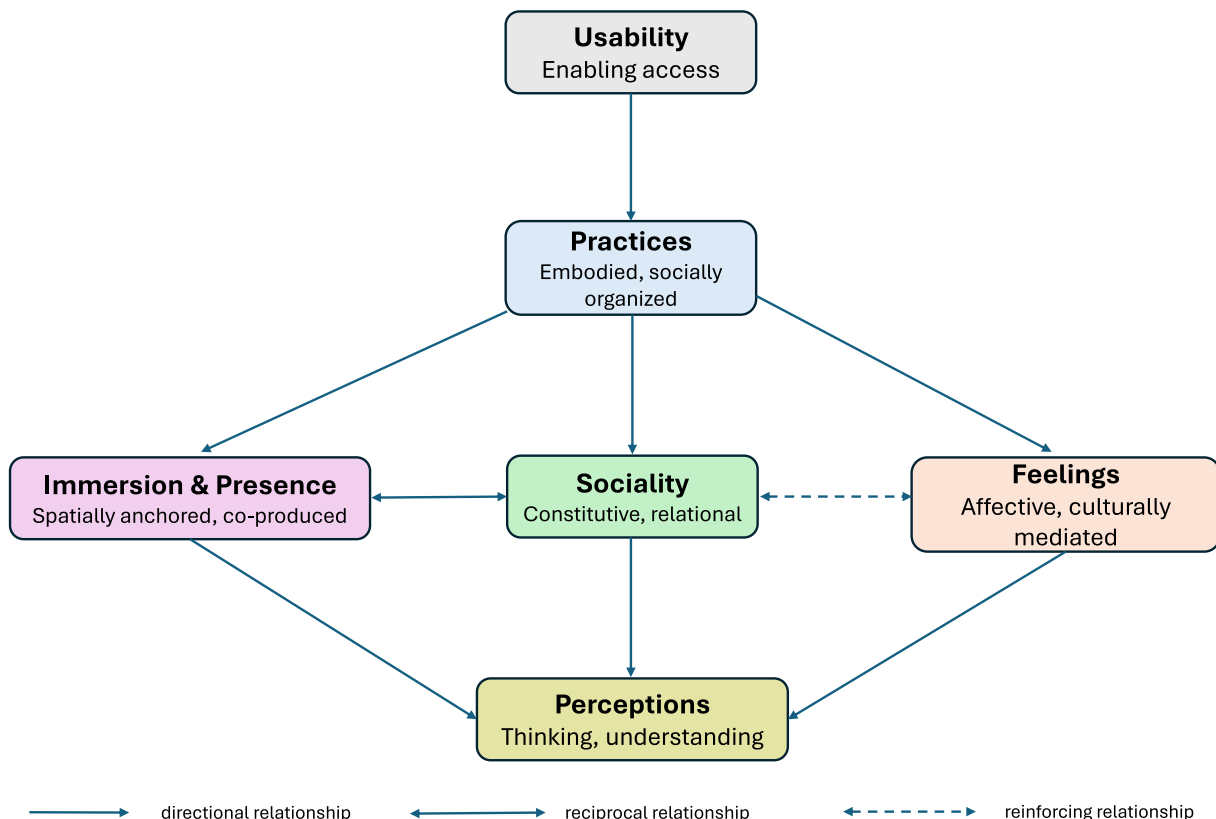


Fig. 1. The six experiential dimensions of the user-centered conceptual evaluation framework and their proposed relational connections.

within situated cultural AR experience:

Practices: the socially organized, embodied forms of doing through which people engage with media and cultural environments, including movement, interaction, exploration, collaboration, and engagement with digital and physical elements (Couldry, 2004; Reckwitz, 2002). In cultural AR settings, these practices extend beyond device interaction to encompass how visitors navigate space, coordinate with companions, and appropriate the environment as part of the encounter.

Perceptions: what users think about the experience (Hassenzahl, 2013a, 2013b), including whether the digital content fits its physical setting, whether the curatorial logic is clear, and what they make of the exhibition and the encounter. In cultural AR settings, these thoughts are shaped by prior knowledge, expectation, and the institutional framing of the encounter.

Feelings: the emotional and affective states elicited during the experience, such as curiosity, excitement, surprise, enjoyment, frustration, or reflection (Kashdan, 2004; Wetherell, 2012; Wetherell et al., 2018). In cultural AR settings, affective responses are bound up with memory, identity, and the significance of place, making them a substantive dimension of interpretive engagement.

Sociality: the social dimensions of experience, including co-presence, shared interaction, conversation, coordination, and the role of others in shaping meaning and enjoyment (Ch'ng et al., 2023; Falk and Dierking, 1992, 2013). In cultural AR settings, companions actively shape what is attended to, how content is interpreted, and how the encounter is remembered, making sociality constitutive of experience.

Immersion and Presence: users' sense of engagement, absorption, and perceived connection between digital and physical environments (Cummings and Bailenson, 2016; Slater, 2009; Witmer and Singer, 1998). In cultural AR settings, this is a quality shaped by how digital content anchors to physical space and how visitor attention shifts between device and environment.

Usability: practical aspects of interaction, such as ease of use, system responsiveness, and technical constraints, understood as enabling or constraining experience (Brooke, 1996; Davis, 1989; Lewis, 2018; Szekeley et al., 2023). In cultural AR settings, usability conditions whether and how visitors can access the experience but does not define its value.

These dimensions are not treated as separate, unconnected aspects of experience but as interacting components of a situated encounter. Usability friction may disrupt practices, social dynamics may deepen affective engagement, and the symbolic meanings of place may shape how content is perceived and remembered. A further premise of the framework is that users are active and reflective participants. They decide how to engage, what to attend to, whether to collaborate, and how to interpret what they encounter. Evaluation must therefore attend to the whole of the encounter, not isolated responses, a requirement that makes the role of context, place, and visitor agency central to the framework's design.

3.3. Context, place and visitor agency

A defining characteristic of many cultural AR experiences is their strong anchoring in physical space. Unlike VR applications that transport users into self-contained environments, AR experiences are embedded in real-world settings and rely on spatial, environmental, and contextual cues. Consequently, experience is shaped not only by digital content but also by the affordances, constraints, and symbolic meanings of the place, including paths, vegetation, architectural features, and the presence of other visitors. A recent scoping review of spatial augmented reality in the cultural heritage sector likewise highlights the importance of architectural context, spatial layout, and visitor movement in shaping how AR installations are perceived and used (Denni et al., 2026). The framework therefore foregrounds spatial and contextual sensitivity as a core evaluative concern, encompassing how users navigate space, how AR content relates to physical surroundings, and how place contributes

to interpretation, atmosphere, and social interaction.

Place is not therefore a backdrop to experience but an active constituent of it, simultaneously shaping practices, feelings, and immersion, and providing the interpretive context through which perceptions and sociality unfold. Together, these elements define a user-centered evaluation approach that is sensitive to cultural context, experiential complexity, and interpretive depth. In the following sections, the conceptual framework is illustrated through the case study of the location-based AR exhibition *Seeing the Invisible* in the National Garden of Athens, showing how these experiential dimensions can guide evaluation design and analysis in AR heritage contexts.

4. Methodology

This section describes how the user-centered conceptual evaluation framework was applied in this exploratory, small-scale study. It presents the overall research design and case study selection, then describes the two data-collection stages (online survey and post-experience interviews), the participant sample and profile, and the ethical and methodological considerations that shape the scope of the findings.

4.1. Research design

The study employed a mixed-methods, user-centered research design to capture the multidimensional and situated nature of experience in a location-based AR cultural environment. In line with the conceptual framework, the aim was not to isolate single variables or optimize technical performance, but to understand how visitors experienced, interpreted, and negotiated the AR exhibition as part of a broader cultural encounter. Quantitative and qualitative methods were combined to explore practices, perceptions, feelings, sociality, immersion and presence, and usability from complementary angles.

4.2. Case study selection

This case study focuses on the AR art exhibition *Seeing the Invisible* presented in the National Garden of Athens, a public, open-air heritage landscape. The exhibition was presented across ten gardens and outdoor cultural venues in nine countries worldwide. The Athens iteration, co-organized by the Municipality of Athens and Outset Greece, is the focus of this study. It offered access to fourteen AR artworks by international contemporary artists through a dedicated mobile application, which visitors used on their own smartphones or tablets (NEON, n.d.). This case was selected for three reasons: (1) it exemplifies a situated AR experience, where digital content is encountered in direct relation to physical space, movement, and environmental context; (2) it foregrounds artistic and interpretive engagement; and (3) its public setting allows the observation of social and collaborative dimensions of experience, including co-visitation and spontaneous interaction among visitors. The study treats the case not as representative of all AR applications but as an analytically rich instance through which to develop and illustrate a user-centered conceptual evaluation framework.

4.3. Participants and recruitment

Data were collected in two stages: an online survey ($n = 37$; 24 complete responses and 13 partial responses) and nine semi-structured individual interviews ($n = 9$). Survey participants were recruited among visitors who had experienced the AR exhibition, both through organized group visits during the last week of September 2023 and through outreach to individual visitors. Six organized visits took place between 22 and 28 September 2023, involving 14 participants who were informed that they would be invited to complete an online questionnaire after the visit, while additional responses came from visitors who encountered the exhibition independently. The online questionnaire was available in Greek and English, enabling participation from both

local and international audiences.

The semi-structured interviews were conducted in Greek with participants recruited from those who had attended the organized visits, and all interviewees were based in Greece. This study is designed as an exploratory, small-scale case study with a small sample predominantly composed of highly educated participants working in heritage and creative professions. The aim is conceptual development and interpretive depth, rather than statistical generalization of the framework dimensions.

4.3.1. Participants' profile

Survey respondents were predominantly female, with a smaller proportion identified as male or other, and most were between 25 and 64 years old. The majority held a university or postgraduate degree, were based in Greece, and almost half self-identified as working in heritage or creative professions.

Among the nine interviewees, most were women aged between 35 and 64, all with university education and the majority with postgraduate qualifications, and all were employed in heritage, museum, or creative sectors in Greece. This profile means the study draws on the perspectives of an informed, culturally engaged, and professionally aware group of visitors, not a representative sample of the general public, and their depth of reflection and interpretive awareness strengthens the qualitative analysis even as it limits generalizability. To protect anonymity while allowing readers to follow individual narratives, interviewees are referred to by pseudonyms summarized in [Table 1](#).

4.4. Data collection

Data were collected through two complementary methods aligned with the experiential dimensions of the framework: an online visitor survey and semi-structured post-experience interviews.

4.4.1. Visitor survey

The visitor survey aimed to capture patterns across the six experiential dimensions: practices, perceptions, feelings, sociality, immersion and presence, and usability, among a broader group of exhibition visitors. The instrument comprised eight sections: general information, social interaction, usability, activities, immersion and presence, feelings, thoughts and perceptions, and expectations.

Questions covered demographic and background information (education, age, place of residence, gender, profession, prior AR experience, and which botanical garden was visited); social aspects of the visit, such as whether they visited alone, with friends, or as part of an organized group; device use and technical issues; artworks seen and most memorable exhibits; activities undertaken around the AR artworks (photography, movement, reading information, posting on social media); Likert-scale items on immersion and presence; a checklist of emotions; attitudinal statements on site-specificity, sustainability, and preferences for onsite versus remote access; and items on expectations and overall satisfaction, followed by an open question for additional comments and an invitation to volunteer for interview participation.

Table 1
Interviewees (pseudonyms, age group, gender).

Pseudonym	Age	Gender
Paige	55-64	F
Ebelyn	45-54	F
Zoetanya	35-44	F
Felicia	55-64	F
Fay	45-54	F
Jackie	45-54	F
Edna	55-64	F
Alan	55-64	M
Nora	35-44	F

F = female; M = male.

Participants who had experienced the AR exhibition were invited to complete an online questionnaire shortly after their visit, via a web link shared during organized visits and through the exhibition organizers. This mode of administration allowed visitors to respond in their own time while the experience was still relatively recent. The survey was available in Greek and in English to accommodate both local and international visitors and was implemented using an online survey platform. The full survey questionnaire, including all items and response scales, is provided in [Supplementary Material S1](#).

4.4.2. Post-experience qualitative assessment

Semi-structured interviews were conducted to gain deeper insight into visitors' lived experiences, interpretive strategies, and reflections beyond the immediate moment of the visit. Visits to the exhibition took place in late September 2023, while interviews were deliberately scheduled with a temporal distance from the visit: one interview was conducted immediately after the visit, four at the end of October, and the remaining four between late December and early January. This spacing was chosen to support post-experience reflection, allowing participants to comment not only on their in-situ impressions but also on how the AR exhibition lingered, faded, or became connected to subsequent cultural and everyday experiences.

The interview guide comprised six thematic blocks: usability, practices, immersion and presence, feelings, perceptions, and social interaction, each linked to the experiential dimensions. Questions addressed enabling conditions and usability, such as downloading and using the app, use of headphones, navigation with the map; embodied and spatial engagement (behavior around artworks, artworks seen and remembered, reactions to having to move to specific locations); spatial integration and temporal experience (fit of AR artworks in the environment, perception of time passing); affective and reflective responses (emotions and thoughts generated by the experience); interpretation and meaning-making (expectations, desired changes, views on sustainability and remote access); and social interaction (whether the visit was shared, conversations during the visit, the influence of sharing on perception). The interview guide (translated into English) is provided in [Supplementary Material S2](#).

Interviews, lasting approximately 50-60 min, were conducted in Greek with visitors recruited from the organized groups. Seven interviews were audio-recorded with consent, while in two cases participants did not consent to recording and detailed notes were taken instead. Full verbatim transcripts were not produced; instead, the material was selectively transcribed and expanded, organized around the six experiential dimensions to support focused, framework-driven analysis.

4.5. Data analysis

Survey data were analyzed using descriptive statistics to identify patterns across the experiential dimensions, while deliberately avoiding reduction to a single composite score or overall "impact" index. The descriptive statistics for each question were computed on all valid responses to that question. Because not all respondents completed the survey, the number of respondents varies across items and is reported with each figure. No data imputation was performed. The goal was to observe how different aspects of experience, such as sociality, immersion, or usability, were perceived and valued, and how they co-occurred across respondents.

Interview material (selective transcripts and expanded notes) was analyzed thematically, using a coding scheme informed by the six experiential dimensions, while remaining open to emergent themes that did not fit neatly within predefined categories. Qualitative material was treated not as a secondary illustration of quantitative findings, but as a primary source for understanding visitors' interpretive strategies, tensions, and ambivalences. The analysis proceeded iteratively, moving between survey patterns and interview narratives to build an integrated

picture of the AR experience in context.

4.6. Ethical considerations and methodological scope

Participation in the study was voluntary. Visitors were informed about the purpose of the research, the nature of the questions, and the use and storage of data; consent was obtained before participation in both the survey and interviews. All data were anonymized in analysis and reporting, and the study adhered to standard ethical principles for research with human participants, with particular attention to data protection and the right to withdraw.

The methodological approach prioritizes depth, contextual sensitivity, and interpretive richness over large-scale generalization. The limited time window, modest sample size, and focus on a single exhibition reflect the realities under which many AR heritage projects are developed and evaluated. These conditions are treated as part of the context the framework is designed to address, namely, how to conduct meaningful, user-centered evaluation of AR in real-world heritage settings with limited resources. The dimensions are conceptually derived and empirically illustrated, not statistically validated. Formal psychometric validation, including reliability testing and factor analysis, lies beyond the scope of this exploratory study.

5. Results

The findings are organized according to the six experiential dimensions proposed in the conceptual framework, showing how they manifested and interacted within the AR exhibition *Seeing the Invisible* in the National Garden of Athens. Percentages refer to respondents who answered each specific survey item.

5.1. Usability: enabling but uneven

Usability functioned primarily as an enabling or constraining layer. While several respondents reported no major problems using the application, others experienced device-related barriers such as incompatibility, storage limitations, GPS instability, battery drain, and patchy internet connectivity in the garden. These issues shaped who could access the AR artworks directly and how smoothly they could move between them.

Interview accounts illustrate this unevenness. One participant noted, “I had already downloaded it before we arrived ... I didn't have any issues” (Nora), whereas another observed, “My phone didn't support the application ... it depended on the device” (Zoetanya). Even among those whose devices worked, technical friction remained: “Only the battery. It drains very fast. And sometimes the GPS would ‘jump’ a bit” (Jackie). Overall, usability shaped comfort and access, but it did not, on its own, determine whether the experience was considered meaningful or enjoyable.

5.2. Practices: embodied and spatial engagement

Survey responses indicate that interaction with the exhibition extended well beyond passive viewing. Among respondents who answered the activities question ($n = 24$; see [Supplementary Fig. S3](#)), 87.50% reported moving in order to position themselves “inside” or around the digital forms, 75% read information about the artists and works on the app, 70.83% took photographs of the AR artworks, and 66.67% were photographed by a companion near the works. Notably, 54.17% also reported simply observing the AR artworks, suggesting that active and contemplative modes of engagement coexisted during the visit. These practices involved bodily repositioning, camera framing, and navigation across the garden to locate geo-specific pins, making movement and device handling central to the encounter.

Interviewees consistently framed the experience as physically dynamic and exploratory. “You couldn't shrink them ... you had to move

back to get the whole picture,” explained Fay, highlighting how artwork scale demanded spatial adjustment. Nora reflected that “you move around the object ... you realize your body is moving in relation to something that isn't physically there,” emphasizing bodily negotiation with immaterial forms. Jackie described the visit as “like a treasure hunt ... looking for the pins in the garden.” These accounts confirm that AR engagement unfolded as an embodied, investigative practice. The combination of geo-specific searching, physical repositioning around digital forms, and movement through open landscape represents what might be described as an exploratory spatial practice, a form of embodied and spatial engagement specific to location-based AR in open heritage environments. [Fig. 2](#) illustrates this spatial negotiation, showing a visitor positioned “inside” *Pneuma* by Mel O'Callaghan.

5.3. Perceptions: hybrid coexistence of real and digital

Survey responses show that visitors formed clear views about the relationship between the AR layer and the garden ($n = 23$; see [Supplementary Fig. S4](#)). The two site-specificity items drew the strongest agreement: 69.57% strongly agreed that the exhibition combined the physical location with the digital experience well, and the same proportion strongly agreed that its availability in the National Garden of Athens was valued. The sustainability item attracted a more distributed



Fig. 2. A visitor (the author) and *Pneuma* by Mel O'Callaghan, an AR artwork from *Seeing the Invisible*, National Garden of Athens, September 2023. Courtesy of the artist and Outset Greece. This image is excluded from the article's CC BY licence and may not be reused without permission from the rights holders.

response, with 47.83% agreeing and 21.74% strongly agreeing that the exhibition prompted reflection on sustainable exhibition practices. Views on remote access were the most divided, with responses spread roughly equally across the five points, indicating that site-specificity was a genuine value for many participants but not universally shared.

Interviewees frequently articulated the experience as a hybrid coexistence of real and digital elements. Fay described the works as “an artwork-ghost ... the coexistence of the real with the non-real,” while Zoetanya characterized the exhibition as “a digital installation that needed space.” Edna emphasized the dialogue between media and setting: “It combined technology very much with nature.” At the same time, several participants felt that relational threads among artworks were not always clear and that an explicit curatorial storyline might have strengthened conceptual coherence. These perceptions suggest that interpretive clarity and narrative framing constitute a distinct evaluative dimension beyond technical performance or scenic novelty, aligning with work that emphasizes site-specific digital layering, curatorial coherence, and the role of interpretation in visitor experience (Economou et al., 2019; Gao et al., 2022; Hassenzahl, 2013a).

5.4. Feelings: wonder, magic, and visceral impact

Affective responses were strongly positive among respondents who completed the feelings checklist ($n = 24$; see [Supplementary Fig. S5](#)). Excitement was selected by 79.17% of respondents and inspiration by 70.83%, while appreciation (37.50%) and happiness (29.17%) followed at some distance. Indifference, anxiety, tiredness, and boredom were each selected by fewer than 9% of respondents, and sadness by none. Participants thus experienced the AR exhibition as engaging and stimulating, with the dominance of positive affect a consistent feature of the checklist data.

Qualitative accounts reveal a more complex picture. Nora described the encounter as “magical ... seeing them sitting on the real trees,” while Zoetanya referred to “this intangible ... a bit of magic.” Fay highlighted the embodied emotional impact: “When you walk inside a digital object ... it makes the message much more visceral.” Interviewees also used terms such as playful, surprising, and thought-provoking to describe the visit. However, emotional intensity did not preclude critique; some participants linked their affective responses to questions about narrative cohesion or the meaning of specific works, indicating that feelings and interpretation were closely intertwined. Notably, several affective responses, including wonder, magic, and visceral impact, were directly bound up with the hybrid coexistence of digital and physical elements. The sensation of walking inside a digital object anchored to real trees and real ground produced emotional intensities that emerged from the encounter between the artworks and their physical setting. [Fig. 3](#) shows *Forget Me Not* by Ori Gersht, illustrating the coexistence of digital and physical elements that participants described in affective terms such as wonder and magic.

5.5. Sociality: shared viewing and collective meaning-making

Sociality emerged as a central component of the experience. Survey data show that only 9.68% of respondents visited the National Garden alone, while 48.39% came with friends, 25.81% during an organized visit, and 16.13% in other social configurations ($n = 31$; see [Supplementary Fig. S6](#)).

Interview material indicates that these social configurations actively structured engagement. Because not all devices supported the application, sharing screens and coordinating movement became part of the visit. “Because not everyone could see the works ... we had to cluster together,” explained Jackie. For Zoetanya, this generated a distinctive mode of engagement: “It was more social because we were talking rather than being alone.” Felicia reflected that “we bonded more; there was a common experience,” and Edna noted that “the fact that we had to share phones made it much more social.” In this sense, technical limitations



Fig. 3. A visitor (the author) and *Forget Me Not* by Ori Gersht, an AR artwork from *Seeing the Invisible*, National Garden of Athens, September 2023. Courtesy of the artist and Outset Greece. This image is excluded from the article's CC BY licence and may not be reused without permission from the rights holders.

sometimes intensified, not diminished, relational engagement, turning collective navigation, discussion, and mutual explanation into core elements of the AR encounter. Sociality was therefore not merely contextual but constitutive of how the exhibition was experienced and remembered, echoing emerging work on social augmented reality in cultural heritage (Ch'ng et al., 2023).

5.6. Immersion and presence: from device awareness to spatial integration

Survey items on presence and spatial experience indicate that 70.83% of respondents agreed or strongly agreed that the AR artworks felt present in the physical environment, and 75% agreed or strongly agreed that they did not realize how time passed during the experience

($n = 24$; see [Supplementary Fig. S7](#)). A somewhat lower proportion (66.67%) agreed or strongly agreed that the digital layer had transformed the garden, suggesting that the sense of temporal absorption and spatial co-presence was more consistently reported than the stronger claim of environmental transformation. These results point to a form of immersion grounded in the simultaneous presence of digital and physical elements, not the full perceptual substitution associated with VR, resonating with presence research that distinguishes different modes of “being there” and emphasizes perceived realism and plausibility ([Hofer et al., 2020](#); [Lombard and Ditton, 1997](#); [Pujol and Champion, 2012](#); [Slater, 2009](#); [Weber et al., 2021](#)).

Interviewees described immersion as a gradual shift from device awareness to spatial integration. “At first, you feel the phone as a barrier. But after a while, you forget you are holding it,” observed Jackie. Nora explained that “because it’s anchored to the ground, your brain starts to treat it as a physical object,” suggesting that spatial anchoring supported perceptual blending of digital and physical elements. Even participants who did not operate a device directly reported immersion: “Even through someone else’s phone, you had the feeling that you entered inside the work,” noted Zoetanya. Immersion in this AR setting was thus relational and negotiated, depending on how devices, artworks, environment, and companions aligned in the shared landscape, a pattern



Fig. 4. *Salt Stalagmite #1* by Sigalit Landau, an AR artwork from *Seeing the Invisible*, National Garden of Athens, September 2023. Screenshot by the author. Courtesy of the artist and Outset Greece. This image is excluded from the article's CC BY licence and may not be reused without permission from the rights holders.

that aligns with findings on spatial anchoring and the importance of context and co-presence in immersive experience ([Denni et al., 2026](#)). [Fig. 4](#) shows *Salt Stalagmite #1* by Sigalit Landau, anchored to the garden path, illustrating the spatial integration described above.

5.7. Interrelation of experiential dimensions

According to the data, the six experiential dimensions did not operate in isolation but shaped one another in ways that reveal the relational logic of the framework. Usability conditioned practices by enabling or restricting who could operate the app and how fluidly they could move between artworks. Practices of movement, exploration, and photographic framing were associated with stronger immersion and presence and with heightened feelings of excitement, inspiration, and wonder. Sociality appeared to reinforce affect and inform perceptions, as the exhibition became a shared exploratory activity in which visitors compared impressions, explained technical aspects to one another, and jointly negotiated navigation and meaning. Perceptions of thematic relevance, narrative coherence, and the value of site-specificity were associated with overall satisfaction and visitors' willingness to attend similar AR exhibitions in the future.

Notably, many respondents indicated that they would like to see another AR contemporary exhibition and that the experience was better than expected, yet a smaller proportion explicitly selected satisfaction statements in the expectations and closing items. This discrepancy suggests that positive excitement and social enjoyment can coexist with critical reflections on curatorial coherence or technical friction. The findings therefore support the need for evaluation approaches that attend to the interplay of embodied, cognitive, affective, and social dimensions, not single composite indicators of usability, immersion, or impact.

6. A user-centered evaluation framework for cultural AR experiences

This section presents the user-centered conceptual evaluation framework in its consolidated form, drawing together the conceptual premises of [Section 3](#) and the empirical findings of [Section 5](#). The framework specifies six interrelated experiential dimensions: *practices*, *perceptions*, *feelings*, *sociality*, *immersion* and *presence*, and *usability*, as the core aspects that evaluation should attend to when AR is embedded in real-world cultural environments. [Table 2](#) summarizes the dimensions and their evaluative focus in cultural AR settings.

In this study, the six dimensions structured every stage of the evaluation design. The survey instrument comprised dedicated sections for each dimension, and the interview guide was organized around six corresponding thematic blocks. The case study of *Seeing the Invisible* shows how these dimensions also interact in practice. Usability constraints affected who could access the works directly and prompted screensharing practices that, in turn, appeared to strengthen sociality. Embodied practices of navigation and positioning accompanied both immersion and affective engagement, while visitors' perceptions of thematic relevance and site-specificity were associated with overall satisfaction and willingness to attend similar exhibitions. The framework is therefore offered as a conceptual resource for researchers and practitioners. Even under modest resource conditions, it can inform the construction of survey instruments and interview guides, structure observation protocols, and support holistic analysis of AR experiences in diverse heritage contexts.

7. Discussion

This paper sets out to reposition AR evaluation in cultural heritage from a system-centered orientation toward a user-centered, experience-oriented approach. Visitors at *Seeing the Invisible* engaged with the exhibition as a situated cultural encounter. Embodied navigation, social

Table 2

Summary of the user-centered conceptual evaluation framework, outlining the six experiential dimensions, their focus in cultural AR settings, and example ways to guide evaluation design.

Dimension	Focus question	What it captures in cultural AR	Example evaluation prompts
Practices	What do visitors actually do with and around the AR layer?	Movement, navigation to pins, positioning “inside” artworks, photographing, reading on-screen information.	“How did you move around the garden to find or view the works?” “Did you take photos or explore from different positions?”
Perceptions	What do visitors think of the exhibition and its content?	Views on the relation between artworks and place, sustainability, remote access, and curatorial coherence.	“How did the digital artworks relate to the garden for you?” “What did the exhibition make you think about?”
Feelings	What kinds of emotions and moods does the experience evoke?	Excitement, wonder, inspiration, playfulness, but also ambivalence or critique.	“Which emotions best describe how you felt after the visit?” “Did any work affect you more strongly, and why?”
Sociality	How does visiting with others shape the experience?	Co-visitation, screen-sharing, conversation, coordination, bonding through a shared activity.	“Who did you visit with, and how did you engage together?” “Did sharing devices or discussing the works influence your experience?”
Immersion and presence	How integrated do the digital works feel with the physical setting?	Sense that artworks are “there,” loss of time awareness, shift from device awareness to spatial integration.	“To what extent did the AR artworks feel present in the garden?” “Did you lose track of time during the visit?”
Usability	Can visitors practically access and operate the AR experience?	Device compatibility, installation, GPS/connectivity, comfort and friction while using the app.	“How easy was it to download and use the application?” “Did technical issues limit your ability to see the artworks?”

Note: These dimensions are not separate evaluation targets. Their relational connections are illustrated in Fig. 1 and elaborated in the Discussion.

interaction, and the physical and cultural context of place shaped what they found meaningful, alongside and often beyond technical performance. This section elaborates the theoretical contribution of the proposed framework, examining its AR-specific evaluative logic and the conceptual boundaries between dimensions.

7.1. From metrics to situated experience

Current AR and XR evaluation frameworks privilege comparability and prediction over contextual interpretation, relying on standardized usability, presence, and impact metrics developed primarily for controlled digital interface settings (Li et al., 2026; Moïnnereau et al., 2022). In cultural heritage contexts, such approaches risk under-representing the embodied, social, and interpretive dimensions through which visitors negotiate AR experiences as culturally situated encounters (Chatsiopolou and Michailidis, 2025; Ramtohul and Khedo, 2021). The proposed framework addresses this gap by realigning AR evaluation with museum and heritage studies’ understanding of visitor experience as relational, situated, and culturally embedded (Falk and Dierking, 2013; Pekarik et al., 1999; Roppola, 2012). This resonates with experience-oriented museum research that conceptualizes visits as unfolding through interactions between visitors, content, space, and institutional narratives.

7.2. AR specificity in heritage environments

AR in open, publicly situated heritage environments presents distinct evaluative challenges that frameworks derived from VR in controlled settings are not designed to address. In such environments, partial visibility of artworks, intermittent connectivity, and the presence of other visitors not participating in the exhibition are not disruptions to the experience but defining features of it. Several patterns in the data are distinctly AR-specific and warrant conceptual attention. The gradual shift from device awareness to spatial integration described by multiple interviewees reflects what the data suggest might be called *relational immersion*, a mode of perceptual blending that is not achieved by the system alone but co-produced through the alignment of artworks, companions, and environment. The practice of repositioning one’s body to place oneself “inside” or around a digital artwork, navigating geo-specific pins across open landscape, constitutes an *exploratory spatial practice*, in which bodily movement itself becomes the means by which visitors establish their position relative to a digital artwork with no fixed material boundary. This pattern resonates with work on spatial engagement and visitor movement in AR heritage settings (Denni et al., 2026). The framework therefore highlights spatial integration, site-specificity, and public situatedness as central evaluative concerns for AR heritage projects, extending heritage-focused AR studies that have noted but not yet fully addressed these contextual factors (Chatsiopolou and Michailidis, 2025; Koo et al., 2019). AR experiences in open, publicly situated heritage environments are also inherently social in character, even when visitors arrive alone, because the setting itself is shared and populated. *Sociality* as a dimension therefore always carries evaluative content in this context, whether it manifests through active companionship or through the presence of other people in the shared space.

7.3. Implications for evaluation practice

Applying the framework in survey items, interview questions, and analysis suggests that rich experiential insight can be generated under realistic project conditions, with modest samples and limited resources. The multidimensional structure supports nuanced interpretation of how different aspects of experience co-occur and sometimes pull in different directions. For heritage practitioners, evaluation designs should systematically attend to practices, perceptions, feelings, sociality, and immersion and presence alongside usability, using a mixed-methods approach that can capture both pattern and narrative variation. More broadly, the framework offers cultural institutions and funders an alternative to purely impact-driven metrics by foregrounding cultural interpretation, visitor agency, and place-based engagement as core indicators of value (Falk and Dierking, 2013; Pekarik et al., 1999).

Used together, the six dimensions let an evaluator understand the experience a visitor has with an AR application as a connected whole, which usability or satisfaction measures alone cannot capture. In practice, each dimension is turned into a set of survey questions and interview questions. For immersion and presence, for example, this took the form of Likert-scale questions on how far visitors felt part of the setting and interview questions on how the AR works sat within the garden and how time seemed to pass. The survey captures patterns across the sample, and the interviews follow the same six dimensions in more depth, with the full instruments given in Supplementary Materials S1 and S2. The questions should be adapted to each exhibition and refined across repeated use, so that each dimension can be measured more consistently over time.

7.4. Theoretical contribution: a reconfiguration of evaluative logic

This user-centered conceptual evaluation framework introduces an AR-specific evaluative logic for cultural heritage contexts (Chatsiopolou and Michailidis, 2025; Li et al., 2026; Moïnnereau et al.,

2022), achieved by reconfiguring concepts drawn from established literature into a new set of evaluative priorities and relational connections among dimensions. Three theoretical aspects of this reconfiguration are developed below.

First, the framework reorders the hierarchy of evaluative concern. In HCI and immersive media evaluation, usability and presence function as primary success indicators (Brooke, 1996; Grassini and Laumann, 2020). The proposed framework repositions both. Usability becomes a condition that enables or constrains access to the experience without defining its value, and presence is reframed as one quality of the encounter among several that evaluation should attend to. This repositioning elevates practices, perceptions, feelings, and sociality as the primary dimensions of evaluative interest. The empirical basis is direct. Usability problems did not prevent meaningful or memorable experiences, while embodied navigation, social interaction, affective response, and engagement were consistently identified as central to what the exhibition meant to visitors.

Second, the framework proposes relational connections among dimensions, suggesting how each dimension may relate to the others within a single encounter. Attending to these connections proved analytically productive and revealed findings that evaluating each dimension separately would have missed. In this case, usability conditioned practices by enabling or restricting who could access the AR layer and how fluidly they could move through it. Practices of navigation and spatial exploration were associated with immersion and presence and with stronger feelings of excitement, wonder, and inspiration. Sociality appeared to reinforce feelings and inform perceptions. Perceptions of thematic relevance, narrative coherence, and site-specificity were associated with how the overall experience was ultimately evaluated. Among visitors in group configurations, device incompatibility and GPS instability did not simply diminish experience but prompted collective navigation, screen-sharing, and sustained conversation that intensified sociality and, through it, affective engagement. A difficulty in one dimension reorganized the experiential dynamics across others, producing richness where degradation might have been predicted.

Third, the framework is designed for the conditions under which most real-world AR heritage evaluation takes place. The standardized instruments most used, including usability scales, presence questionnaires, and impact metrics, were developed for controlled settings with stable technical conditions and individual users (Li et al., 2026; Moinnereau et al., 2022). Heritage practitioners rarely have access to these conditions. AR applications in open, public environments involve variable technical performance, mixed visitor groups, modest sample sizes, and limited evaluation resources (Chatsiopolou and Michailidis, 2025). The framework proposed here takes these conditions as its starting point. Its six dimensions can guide how researchers design instruments and interview guides, structure fieldwork, and interpret findings under realistic project conditions, making it a practical as well as conceptual contribution to AR heritage evaluation.

8. Limitations

This study was conducted in a location-based AR art exhibition in a single public garden, with a small sample and a specialist participant profile, and does not claim statistical representativeness, broad transferability, or formal validation of the framework dimensions. First, the sample is predominantly composed of heritage and creative professionals. The depth and reflexivity of their responses are analytical strengths, but the findings cannot be generalized to broader visitor populations without further empirical application across different AR heritage contexts.

Second, the study is based on a single case. *Seeing the Invisible* is a specific type of location-based, outdoor AR art exhibition in the National Garden of Athens. The framework has been developed and illustrated in this context, and its applicability to indoor museum AR, AR in historic built environments, gamified heritage AR, or non-art-focused

applications remains to be tested. Future research should apply and adapt the framework across multiple AR and XR heritage projects to assess which dimensions are stable across contexts and which require modification.

Third, the quantitative analysis relies solely on descriptive statistics. No reliability testing, factor analysis, or validity assessment of the six dimensions has been carried out. The relational connections among the dimensions shown in Fig. 1 are proposed on conceptual grounds and were not empirically tested in this study. Their direction and strength remain open questions for future research. Formal validation, including application across multiple AR heritage contexts and the development of reliable measurement approaches for each dimension, is identified as a priority for future work.

Fourth, the temporal structure of the data collection, with survey responses collected shortly after the visit and interviews conducted over a period of several months, means that some interview accounts reflect a degree of retrospective reconstruction. This was a deliberate methodological choice intended to capture post-experience reflection, but it also means that the study does not include real-time behavioral data from within the exhibition. In-situ observation or experience sampling methods could complement the present approach in future studies. The design is cross-sectional and does not follow the same visitors over time. Although the interviews were spaced over several months to capture post-experience reflection, longer-term or longitudinal questions remain open for future research.

Fifth, the author organized the group visits and conducted the interviews, a dual role that may have introduced social desirability bias in interview responses. Participants were aware of the author's involvement and may have moderated their critical responses accordingly. This is an inherent limitation of this study design.

These limitations are acknowledged as specifications of the context in which the framework has been developed. As an exploratory case study, this paper prioritizes conceptual development and interpretive depth, leaving statistical generalization and psychometric validation to future work. The framework remains a useful starting point for researchers and practitioners working in comparable conditions.

9. Conclusions

This paper has argued for a shift from system-centered, metric-driven evaluation of AR toward a user-centered, experience-oriented approach tailored to cultural heritage contexts (Li et al., 2026; Moinnereau et al., 2022). Grounded in an exploratory mixed-methods case study of *Seeing the Invisible* in the National Garden of Athens, it identified six interrelated experiential dimensions: *practices, perceptions, feelings, sociality, immersion and presence*, and *usability*, and showed how they interact in a location-based AR exhibition. The sample was small and predominantly composed of heritage and creative professionals, the design exploratory, and the analysis descriptive rather than inferential. These limitations reflect the realities of evaluating AR in real-world heritage settings with limited resources, and it is precisely this context that this conceptual evaluation framework is designed to address.

Building on these findings, this paper proposed a user-centered conceptual evaluation framework that reconceptualizes AR experience as a cultural, social, and spatial phenomenon. The framework can guide the design of survey questions, interview approaches, and observational analysis, enabling heritage institutions to undertake nuanced evaluations even under modest resource conditions. Its novelty lies in the reconfiguration of well-established concepts into a coherent, AR-specific evaluative logic for cultural heritage contexts. This is achieved by reordering the hierarchy of evaluative concern, specifying relational connections among dimensions, and clarifying the conceptual boundaries between them, responding directly to the absence of such a logic identified in the wider literature (Chatsiopolou and Michailidis, 2025).

By foregrounding interpretation, sociality, and place alongside usability and immersion, this study aligns AR evaluation with experience-

oriented museum research (Falk and Dierking, 2013; Roppola, 2012) and contributes a user-centered conceptual evaluation framework for future AR and XR heritage projects. Further applications across different sites, formats, and visitor populations are needed to test the framework's applicability in diverse AR heritage contexts and to explore its value for comparative studies of immersive cultural experiences.

Data availability statement

The datasets generated and analyzed during this study are not publicly available to protect participant privacy and confidentiality as guaranteed in the informed consent process. Anonymized summary data supporting the conclusions of the article may be available from the corresponding author upon reasonable request and subject to appropriate ethical review.

CRedit authorship contribution statement

Sophia Bakogianni: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing (original draft), Writing (review and editing).

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used Perplexity and Claude (Anthropic) to improve the readability and language of the manuscript in English. The author also used Claude to write the Python code that generated the supplementary charts (Fig. S3–S7) from survey data collected by the author. After using these tools, the author reviewed and edited the content as needed and takes full responsibility for the content of the published article.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Open access publication of this article was funded by HEAL-Link under an agreement between Elsevier and HEAL-Link.

Declaration of competing interest

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

I would like to express my gratitude to all the people who participated in this study for their time, support, and contribution to the project. I am particularly grateful to Mrs. Artemis Stamatiadis, Director of Outset Greece, for granting permission to conduct the study at *Seeing the Invisible* in the National Garden of Athens. I also thank her for granting permission to publish screenshots of the artworks in this article and in the graphical abstract of the paper. This research forms part of my postdoctoral project, and I would also like to thank my supervisors, Dr. Kostas Karpouzis, Dr. Stavros Kaperonis and Prof. Yannis Skarpelos, for their guidance and support throughout the development of this work.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.daach.2026.e00598>.

References

- Brooke, J., 1996. SUS-A quick and dirty usability scale. In: Jordan, P.W., Thomas, B., McLelland, I., Weerdmeester, B.A. (Eds.), *Usability Evaluation in Industry*. Taylor and Francis, London, pp. 189–194.
- Ch'ng, E., Cai, S., Feng, P., Cheng, D., 2023. Social augmented reality: communicating via cultural heritage. *J. Comput. Cult. Herit.* 16 (2), 29, 1–26.
- Chatsiopolou, A., Michailidis, P.D., 2025. Augmented reality in cultural heritage: a narrative review of design, development and evaluation approaches. *Heritage* 8, 421.
- Couldry, N., 2004. Theorising media as practice. *Soc. Semiot.* 14, 115–132.
- Cummings, J.J., Bailenson, J.N., 2016. How immersive is enough? A meta-analysis of the effect of immersive technology on user presence. *Media Psychol.* 19, 272–309.
- Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Manag. Inf. Syst. Q.* 13, 319–340.
- Denni, M., Spallazzo, D., Ceconello, M.A., 2026. Investigating spatial augmented reality technology in the cultural heritage sector: a scoping review. *Electronics* 15, 540.
- Devine, C., Tarr, M., 2019. The digital layer in the museum experience. In: Giannini, T., Bowen, J.P. (Eds.), *Museums and Digital Culture: New Perspectives and Research*. Springer, Cham, pp. 295–307.
- Economou, M., Young, H., Sosnowska, E., 2019. Evaluating emotional engagement in digital stories for interpreting the past. The case of the hunterian Museum's antonine wall EMOTIVE experiences. In: 2018 3rd Digital Heritage International Congress & 24th International Conference on Virtual Systems and Multimedia (VSMM). IEEE, San Francisco, CA, pp. 1–8.
- Falk, J.H., Dierking, L.D., 1992. *The Museum Experience*. Whalesback Books, Washington D.C.
- Falk, J.H., Dierking, L.D., 2013. *Museum Experience Revisited*. Taylor & Francis, Oxon and New York.
- Gao, Z., Wang, A., Hui, P., Braud, T., 2022. Bridging curatorial intent and visiting experience: using AR guidance as a storytelling tool. In: *Proceedings - VRCAI 2022: 18th ACM SIGGRAPH International Conference on Virtual-Reality Continuum and its Applications in Industry*. Association for Computing Machinery, Inc, 5, 1–10.
- Grassini, S., Laumann, K., 2020. Questionnaire measures and physiological correlates of presence: a systematic review. *Front. Psychol.* 11, 511710.
- Hassenzahl, M., 2013a. Experiences before things: a primer for the (yet) unconvinced. In: *CHI 2013: Extended Abstracts on Human Factors in Computing Systems*. ACM, New York, USA, pp. 2059–2067.
- Hassenzahl, M., 2013b. User experience and experience design. In: Soegaard, M., Dam, R. F. (Eds.), *The Encyclopedia of Human-Computer Interaction*. Interaction Design Foundation.
- Hofer, M., Hartmann, T., Eden, A., Ratan, R., Hahn, L., 2020. The role of plausibility in the experience of spatial presence in virtual environments. *Front. Virtual Real.* 1, 510700.
- Kashdan, T.B., 2004. Curiosity. In: Peterson, C., Seligman, M.E.P. (Eds.), *Character Strengths and Virtues*. Oxford University Press, New York, pp. 125–141.
- Kleifodimos, A., Evagelou, A., Gkoutzios, S., Matsiola, M., Vrigkas, M., Yannacopoulou, A., Triantafyllidou, A., Lappas, G., 2023. Creating location-based augmented reality games and immersive experiences for touristic destination marketing and education. *Computers* 12, 227.
- Koo, S., Kim, Jinyoung, Kim, C., Kim, Jeeyeop, Cha, H.S., 2019. Development of an augmented reality tour guide for a cultural heritage site. *J. Comput. Cult. Herit.* 12 (4), 24.
- Laugwitz, B., Held, T., Schreppe, M., 2008. Construction and evaluation of a user experience questionnaire. *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)* 5298 LNCS 63–76.
- Lessiter, J., Mitchell, S., Ferrari, E., Borden, P., Bakshi, H., Freeman, J., 2018. *Evaluating Immersive User Experience and Audience Impact*. Nesta and i2 Media Research for Digital Catapult, London.
- Lewis, J.R., 2018. The system usability scale: Past, present, and future. *Int. J. Hum.-Comput. Interact.* 34, 577–590.
- Li, X., He, W., Kristensson, P.O., 2026. How do we evaluate experiences in immersive environments? In: *Proc. 2026 CHI Conf. Hum. Factors Comput. Syst. (CHI '26)*. ACM, Barcelona, Spain, pp. 1–25.
- Lombard, M., Ditton, T., 1997. At the heart of it all: the concept of presence. *J. Comput.-Mediat. Commun.* 3 (2).
- Moineau, M.-A., de Oliveira, A.A., Falk, T.H., 2022. Immersive media experience: a survey of existing methods and tools for human influential factors assessment. *Qual. User Exp.* 7 (1), 5.
- NEON, n.d. *Seeing the Invisible* [WWW Document]. URL <https://neon.org.gr/en/exhibiti on/seeing-the-invisible-2/> (accessed 30.06.26).
- Pekarik, A.J., Doering, Z.D., Karns, D.A., 1999. Exploring satisfying experiences in museums. *Curator Museum* 42, 152–173.
- Pujol, L., Champion, E., 2012. Evaluating presence in cultural heritage projects. *Int. J. Herit. Stud.* 18, 83–102.
- Ramtohl, A., Khedo, K.K., 2021. User experience and engagement in augmented reality systems for the cultural heritage domain. In: Geroimenko, V. (Ed.), *Augmented Reality in Tourism, Museums and Heritage: A New Technology to Inform and Entertain*. Springer, Cham, pp. 227–256.
- Reckwitz, A., 2002. Toward a theory of social practices: a development in culturalist theorizing. *Eur. J. Soc. Theor.* 5, 243–263.
- Roppola, T., 2012. *Designing for the Museum Visitor Experience*. Routledge, New York; Abingdon, Oxon.
- S. Bakogianni, 2022. *Understanding Museum Social Media Experiences*. Open University of Cyprus, Nicosia, Cyprus. <http://hdl.handle.net/10442/hedi/53088> (PhD thesis).

- Schreiber, J.B., Pekarik, A.J., Hanemann, N., Doering, Z., Lee, A.J., 2013. Understanding visitor engagement and behaviors. *J. Educ. Res.* 106, 462–468.
- Schrepp, M., Hinderks, A., Thomaschewski, J., 2017a. Construction of a benchmark for the user experience questionnaire (UEQ). *Int. J. Interact. Multimed. Artif. Intell.* 4, 40–44.
- Schrepp, M., Hinderks, A., Thomaschewski, J., 2017b. Design and evaluation of a short version of the user experience questionnaire (UEQ-S). *Int. J. Interact. Multimed. Artif. Intell.* 4, 103–108.
- Shi, H., Li, J., Xue, L., Song, Y., 2023. OperAR: using an augmented reality agent to enhance children's interactive intangible cultural heritage experience of the peking opera. In: *UIST 2023 Adjunct - Adjunct Proc. 36th Annual ACM Symposium on User Interface Software Technology*, 2, 1–3.
- Siang, T.G., Aziz, K.B.A., Ahmad, Z.B., Suhaifi, S. Bin, 2019. Augmented reality mobile application for museum: a technology acceptance study. In: *2019 6th International Conference on Research and Innovation in Information Systems (ICRIIS)*. IEEE, Johor Bahru, Malaysia, pp. 1–6.
- Slater, M., 2009. Place illusion and plausibility can lead to realistic behaviour in immersive virtual environments. *Philos. Trans. R. Soc. B Biol. Sci.* 364, 3549–3557.
- Szekely, D., Vert, S., Rotaru, O., Andone, D., 2023. Usability evaluation with eye tracking: the case of a Mobile augmented reality application with historical images for urban cultural heritage. *Heritage* 6, 3256–3270.
- Wang, F., Peng, X., Wang, Y., Fan, W., Wang, K., Du, Y., 2025. Adopting AR wayfinding in heritage tourism: extending the UTAUT in cultural contexts. *npj Herit. Sci.* 13, 484.
- Wang, N., Jia, C., Wang, J., Li, Z., 2025. Identifying key factors influencing immersive experiences in virtual reality enhanced museums. *Sci. Rep.* 15, 31990.
- Weber, S., Weibel, D., Mast, F.W., 2021. How to get there when you are there already? Defining presence in virtual reality and the importance of perceived realism. *Front. Psychol.* 12, 628298.
- Wetherell, M., 2012. *Affect and Emotion: a New Social Science Understanding*. SAGE Publications, London.
- Wetherell, M., Smith, L., Campbell, G., 2018. Introduction: affective heritage practices. In: *Emotion, Affective Practices, and the Past in the Present*. Routledge. Taylor & Francis Group, London and New York, pp. 1–22.
- Witmer, B.G., Jerome, C.J., Singer, M.J., 2005. The factor structure of the presence questionnaire. *Presence Teleoperators Virtual Environ.* 14, 298–312.
- Witmer, B.G., Singer, M.J., 1998. Measuring presence in virtual environments: a presence questionnaire. *Presence Teleoperators Virtual Environ.* 7, 225–240.