Exploration Games: Can Game-Guided Systems Support Users in Automated Exhibition Sites?

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Abstract. This article delves into the potential of incorporating elements from adventure games into museum exhibitions, with a particular focus on automated exhibition sites. We advocate that principles derived from adventure games can adeptly bridge the two primary expectations of exhibitions: *enlightenment* and *experience*. Exploration-based games, such as *Explore the Redoubt* (XTR) crafted for automated venues, enable users to fulfill both these objectives. XTR, conceived to address the prevailing research voids, integrates game mechanics into the automated exhibition environment, enhancing visitor motivation and engagement. It harnesses interactive digital mediums to present cultural heritage in a relaxed, informal manner.

Existing research scarcely touches upon the design of experiential learning games developed for automated sites, which encompass both indoor and outdoor displays. Our methodology contemplates the transformation of visitor conduct at exhibitions, morphing them into avid knowledge seekers. We challenge the adequacy of current user experience models in portraying exhibitions striving to provide both enlightenment and an immersive experience. Consequently, we introduce a framework for museum interactions that deeply engages users, urging them to define their exploration trajectories, seamlessly fusing enlightenment, and engagement. Our study is set in a 17th-century redoubt where initial observations indicated greater outdoor engagement compared to indoor spaces. This observation fueled our initiative to amplify indoor visitor participation.

After testing XTR with 30 participants and employing a combination of observations and interviews, we derived key insights on designing digital exploration games that seamlessly combine enlightenment and engagement. We conclude with three design strategies to enhance visitor curiosity and exploration.

Keywords: Cultural Heritage · Mixed Reality Game · Exploration-Based Learning

1 Introduction

Museums are progressively transforming into knowledge playgrounds, merging game-based elements with mobile technologies to intertwine education and entertainment. The journey from 1950s analog audio guides to today's sophisticated multimedia devices

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showcases how museum technology has warmly embraced the *Bring Your Own Device* (BYOD) trend [1–3]. This shift is largely attributed to the ubiquity of personal devices such as smartphones. While adopting BYOD significantly cuts down on hardware expenses for museums, it transfers the onus of maintenance and security onto the users. Importantly, user preferences for such platforms vary depending on the context.

Our study stands out as it zeroes in on fully automated exhibition sites where no human staff is available. Even though some visitors might approach this setup with a touch of apprehension, recent strides in technology, including advancements in AI, augmented reality, and virtual guides, have aptly risen to meet the challenge. Pioneering ideas like virtual museums and telepresence robots are pushing the envelope, allowing cultural experiences to transcend traditional physical confines [4–11].

In this light, we present *Explore the Redoubt* (XTR), a mobile game specifically designed for automated venues, aiming to enrich visitor interactions. Its core objectives are to navigate, spark curiosity, and promote exploration. Central to our research is evaluating how effectively XTR functions in automated settings and its proficiency in addressing diverse individual interests.

The ensuing sections delve into the multifaceted role of technology in museums, the delicate balance between education and entertainment, and an analysis of visitor motivations and tools from a human-computer interaction (HCI) perspective. This HCI foundation played a pivotal role in conceptualizing XTR. Our concluding sections will elucidate the testing and evaluation procedures for XTR, presenting a compendium of design strategies and invaluable lessons acquired, to enlighten future design, development, and research endeavors.

1.1 Museum Discourses and HCI Research

Museums, historically celebrated for their extensive and eclectic collections, have undergone a transformation from mere cabinets of curiosity to vibrant cultural epicenters interwoven with tourism and entertainment. For practitioners in the field of Human-Computer Interaction (HCI) aspiring to make their mark in this domain, grasping the foundational tenets of museum studies is imperative [12]. This knowledge equips them to architect automated design solutions tailored for exhibition venues.

For the past two decades, the nexus of educational enlightenment and immersive experience has sat at the heart of museum deliberations [13–17]. Here, *enlightenment* delves into the pedagogical, fact-driven facet of displays, while *experience* resonates with the emotive, narrative-driven side. This intricate dance between the two profoundly molds the exhibition's aura, determining its ability to resonate, facilitate, and guide visitors.

Yet, as museums are increasingly perceived as extensions of the entertainment sphere, curators grapple with ensuring exhibits are both informative and engaging. Genevieve Bell's work, "Making Sense of Museums," [18] also probed the pivotal question: should museums champion education over entertainment, or the other way round? While the broader narrative in museum studies echoes this bifurcation, a contingent of scholars champions a more integrative model—melding enlightenment and experience, instead of compartmentalizing them. When dissecting museum encounters, it's essential to regard them as distinctive, standalone events, offering respite from the mundanities of daily

life. Unfortunately, the discourses encompassing enlightenment and experience often err by viewing them in stark binary [13, 14, 16, 19, 20].

Technological strides have ushered museums into an era of interactive and gamified features, spanning from intriguing digital quizzes to elaborate gaming installations. These innovations have rendered museum spaces more captivating, particularly for younger audiences adept with interactive digital mediums. Thus, the traditional museum *visitor* is now recast as a *user*, immersing themselves in enlightening experiential content [12, 21–24].

However, this pivot towards gamification and interactivity has not been universally lauded. Purists hold a torch for the time-honored, structured impartation of knowledge, relegating entertainment to the back seat. This age-old tug-of-war between enlightenment and experience remains a staple in modern museum design narratives [25, 26].

Harmonizing the educational and experiential elements is no mean feat, occasionally culminating in designs that appear contrived or fragmented. When the experiential takes precedence, the educational can feel like an afterthought, and the reverse holds true as well. These dynamics critically shape the user experience, further underscored by the burgeoning role of digital interactivity in displays.

1.2 Explorative Exhibitions

During the 1960s and 1970s, the landscape of education underwent a significant shift, with concepts of informal education gaining traction [27]. This evolution cast museums in a new light, presenting them as epicenters for informal lifelong learning [28–30]. Hein (1998) introduced a series of pedagogical models tailored for museum education, among which were the didactic expository and stimulus-response models, both grounded in traditional paradigms emphasizing preset knowledge and passive learning [31]. Conversely, his discovery framework and constructivist models championed the ethos of exploration and self-driven interpretation.

In a similar vein, Kolb's (2015) experiential learning theory revolves around a cyclical process comprising four distinct stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation [32, 33]. Both Hein's constructivist approach and Kolb's model resonate with the idea of learning as an active endeavor, punctuated by bouts of introspection. Such immersive experiences find their ideal breeding ground in interactive exhibitions, paving the way for profound comprehension and enlightenment [34–39].

Building on this, Csikszentmihalyi and Hermanson (1994) spotlighted the pivotal role of curiosity as a catalyst for museum-based learning [40]. Stimulating exhibits that ensnare the visitors' attention can elevate the experiential learning quotient. A plethora of academic investigations corroborates the intrinsic connection between curiosity and learning, underlining how curiosity simultaneously fuels and is refined by the learning trajectory [41–47]. Within the confines of an exhibition, a spark of curiosity can serve as a beacon, urging visitors to traverse the space uninhibitedly. When orchestrated adeptly, such exploration can usher in a *flow* state—a zenith of immersive learning that melds intellectual engagement with personal evolution [48].

Nonetheless, attaining this coveted flow state mandates intentional and meticulous design strategies. Exhibits ought to offer a spectrum of engagement avenues—be it emotional, cognitive, or sensory. When information is foisted upon visitors as indisputable fact, it can dampen their exploratory zeal. On the flip side, exhibits that fall short of visitor anticipations or skimp on interactive facets can cause curiosity to ebb, potentially derailing the transformative learning journey. Therefore, Csikszentmihalyi and Hermanson make a case for curating experiences that artfully interweave curiosity and exploration, laying the groundwork for an idyllic learning milieu [40].

1.3 Curiosity and Exploration

Curiosity and exploration, two intrinsically linked concepts, permeate a multitude of disciplines [41, 46, 49–51]. Interest, often dubbed as the curious emotion, emerges as a cornerstone of human motivation and a lens to understand personality nuances.

This kinship also finds resonance in artificial intelligence, where curiosity informs learning and problem-solving trajectories [52–54]. Exploration, on the other hand, can oscillate from a spontaneous bias towards novelty to a structured pursuit of information birthed from curiosity. In this context, encounters with unfamiliar and intricate stimuli activate a reward mechanism, championing the exploration of novelty and anchoring learning [55].

Museum-going experiences are intimately personal, sculpted by the trinity of physical, social, and individual contexts the exhibit inhabits. This active engagement traverses a triad of emotional, intellectual, and social realms. User movement patterns within exhibitions have been intrinsically linked to exploration [47, 56–58]. Different visitor archetypes reveal diverse motivations, among which stands the figure of the explorer, an archetype galvanized both by and through the prism of curiosity.

In 1969, the Exploratorium in San Francisco heralded a seismic shift in museum engagement, extolling the virtues of interactivity and play [59]. These avant-garde institutions, with their accent on experiential learning, drew inspiration from John Dewey's ethos [43, 60]. Dewey postulated that authentic learning is inextricably tethered to action [43].

The meteoric rise of technology has recalibrated the museum-going experience. Mobile, contextual learning paradigms within exhibitions influence user behaviors. As visitors evolve with growing technological proficiency, they harbor amplified expectations for immersive, digital experiences. Emerging technologies not only recast museum communication paradigms but also rewrite design blueprints. Through their offerings, visitors are ushered into a realm of technologically-mediated, novel interpretations of exhibits [12, 61–65].

Striking the balance between enlightenment and experience continues to be the north star of museum design. This research pivots towards game design as the bridge. Games, celebrated for their alchemy of blending education with entertainment, harmonize with pedagogic learning models [2, 22, 66].

Constructivist and experiential learning paradigms amplify the ethos of exploration, resonating with Csikszentmihalyi's (1990) iconic *flow* construct [48]. He contended that quintessential museum learning is a holistic affair, engaging both the mind and the body,

and homing in on innate motivations. Curiosity is the lifeblood of this paradigm, nurturing exploration, immersion, and awakening a reward system geared towards novelty [40].

In synthesizing the intricate web of curiosity, exploration, interest, and motivation, a foundation is laid for devising a mobile game guide tailored for users. Adventure games, typified by their curiosity-fueled puzzle-solving ethos, mirror our theoretical scaffolding. Transmuting users into players, these games beckon them to traverse exhibitions in a ludic ambiance. Such games craft bespoke experiences, welding knowledge imbibing with tangible real-world applications.

2 Designing Explore the Redoubt

Curiosity and exploration are central to the design of XTR. In particular, we have zeroed in on curiosity because it fosters exploration, a critical activity through which organisms seek information that they can use to make effective and rewarding decisions [55, 67, 68]. Furthermore, exploration is critical to obtaining information to discover how the world works [67]. In this design, curiosity propels exploration, which is crucial for comprehending environments, and aims to incentivize visitors to interact more proactively with the exhibition site.

This study assesses the influence of XTR on user experiences within automated exhibitions, leveraging the allure of adventure-themed mobile games to stimulate exploration. While the presence of mobile games in museums is not a novel concept, the distinct emphasis here is on nurturing exploration and promoting self-directed learning.

Human-computer interaction (HCI) research has extensively examined the potential of mobile devices in the realm of mixed reality gaming [22,69–74]. Yet, a notable research lacuna persists concerning the role of exploration-centric components in automated contexts.

We posit that harmonizing mobile technology with mixed reality gaming paradigms can amplify the efficacy of self-directed automated exhibitions. The overarching objective is to kindle curiosity, sustain interest, and proffer a compelling visitor experience. Our investigation delves into the way mobile platforms facilitate exploration and autonomy, placing particular emphasis on digital adventure games tailored to the diverse requirements of automated exhibitions.

To this end, we developed XTR, a geolocation-centric game tailored for the Hals Museum and Redoubt (HMR) in Denmark. This initiative seamlessly intertwines gaming elements with pedagogical content. Consequently, XTR aspires to direct users within automated exhibitions, incorporating game dynamics to encourage expansive exhibition exploration and showcase cultural heritage through an immersive digital lens.

2.1 Context: Hals Museum and Redoubt

The Hals Museum and Redoubt (HMR), nestled in the coastal village of Hals in Northern Jutland, Denmark, is a testament to cultural heritage, fortified within the ramparts of a 1600s redoubt. In May 2018, it underwent a transition from a conventional museum

structure to an automated model. This innovation marked the pioneering step among multiple sites overseen by the Historical Museum of Northern Jutland. Unlike their larger counterparts, which usually benefit from generous funding and commercial oversight, smaller heritage sites such as the HMR grapple with distinct economic constraints, which inevitably shape their growth trajectories. The designation of HMR as a protected site imposes further restrictions; for instance, outdoor exhibits cannot incorporate conventional informational aids like posters, which curtails certain design possibilities.

In its current state, devoid of onsite staff, HMR is underpinned by automated security mechanisms, encompassing features like timed locks and surveillance cameras. This metamorphosis is driven by a vision to streamline operations across smaller venues, tackling fiscal hurdles by providing complimentary access, thereby sidestepping potential shutdowns due to financial inadequacies.

Narratively, HMR is a tapestry of interwoven stories, absent of a linear trajectory. It traverses epochs, from the inception of the redoubt in the 1600s, its tenure as a German stronghold during World War II, to diverse exhibits showcasing maritime relics and narratives pertaining to the coastal village and its environs. The exhibition also delves into portrayals of Hals' quotidian life since the 1970s and elucidates on the village's ecclesiastical heritage.

Empirical observations, both prior to 2016 and after the 2018 overhaul, underscore palpable shifts in visitor engagement. In the open spaces, patrons were observed to indulge in playful exploration, utilizing the expanse for recreational pursuits, exemplified by activities such as cavorting around the cannons (refer to Fig. 1: left). Conversely, within the indoor confines, the elder demographic exhibited a propensity for contemplative perusal, while their younger counterparts seemingly exhibited detachment. Nonetheless, replica soldier attires, proffering hands-on engagement, evoked universal fascination (as depicted in Fig. 1: right).

Fig. 1. Left: An aerial overview of the exhibition site, with the house museum containing the exhibited artifacts. Source: Google Maps. Right: A visitor poses with the replica costume

There were challenges in conveying the multifaceted narrative, guiding visitors, and highlighting the redoubt's significant features. Many visitors overlooked the architecturally significant powder chamber and the vital ravelin drawbridge, even while using it. A typical visit to the museum lasted 30–60 min, which is consistent with other studies where the timespan has been reported to be 31–105 min for families [75]. The average attention span of a visitor to an exhibition is about 30–45 min [76].

2.2 Curiosity and Exploration Framed as *Exploration Games*

In response to prevailing challenges—especially the need for thematic cohesion and the imperative to guide visitors towards the less conspicuous segments of the redoubt—XTR was conceived. Its primary objective was to provide thematic unity to the exhibition site, spur users' curiosity with exploration facets, and consequently enhance the overall visitor experience.

The paradigm of exploration games serves as an effective conduit for melding enlightenment with experiential immersion within an exhibition space. Succinctly, the game aims to seamlessly integrate education, entertainment, and guidance, thus ameliorating the user experience in an automated setting. To address the challenges outlined, this research pivots to the adventure games genre, drawing upon its array of design elements and mechanics, which collectively shape the architecture of XTR. In its current iteration, XTR employs two core explorative components: thematic/topical coherence achieved via storytelling and puzzle-solving, and directionality facilitated by a scavenger hunt motif.

Subsequent sections will delve deeper into the specific design patterns culled from adventure games that have been integrated into XTR. It's noteworthy to mention, however, that the prioritization of goals—be it primary, secondary, or tertiary—was intrinsically tied to individual users, calibrated according to their unique interests and motivations.

2.3 System Design and Explorative Elements of XTR

The game design of XTR emerged from a cooperative co-design process involving the HMR custodian, curator, an elementary school teacher, a museum inspector, and the game's development team (see Fig. 2). This method emphasizes the importance of multidisciplinary involvement in crafting digital narratives for museum settings, with co-design being pivotal [77, 78]. Such participatory methods in the cultural and educational arenas allow domain experts to collaboratively design interactive storytelling solutions [79, 80]. While museum professionals and the teacher determined the content, developers oversaw the technical side. The curator's role was advisory, leveraging visitor insights.

Fig. 2. Left and right photos show design workshops with a team of custodians, curators, schoolteachers, the museum inspector, the exhibition designer, and application developers.

The game's intent was to instill a sense of discovery through exploration, all grounded in the physical traversal of the museum site. Although immersion through physical

exertion wasn't the primary focus of this study, it remains a potential avenue for future research.

Workshop discussions settled on a smartphone game app using cross-platform Bluetooth frameworks compatible with iBeacon and Eddystone protocols. Bluetooth beacons, offering clues tied to specific locations, were integrated to leverage the physical indoor and outdoor exhibit spaces. These were selected for their unobtrusive integration capabilities. Without on-site WiFi, standalone networks between mobile devices and beacons, termed "fog" networks [51], were established.

XTR, is a location-based game built in UNITY for modern smartphones with Bluetooth and 3D-graphic features. It's available on both Android and iOS through BYOD approach. Users downloaded it from the respective app stores and received instructions on-site. The game employs 15 Bluetooth beacons (10 indoor, 5 outdoor) to guide users towards key points in the exhibition, nudging them towards lesser-explored areas of the redoubt.

2.4 Game Mechanics

The game, XTR, combines two modes of play: *explorative exhibition* and *exhibition quiz*. The *node proximity* overview (see Fig. 3) guides players using iconography and labels, resembling a "hot or cold" system, with colors indicating the beacon's distance. The default mode is the explorative exhibition: an outdoor game spanning the redoubt. In contrast, the exhibition quiz takes place inside the armory where the primary exhibits reside. Both modes utilize scavenger hunts and puzzle-solving, but their unlocking mechanisms differ.

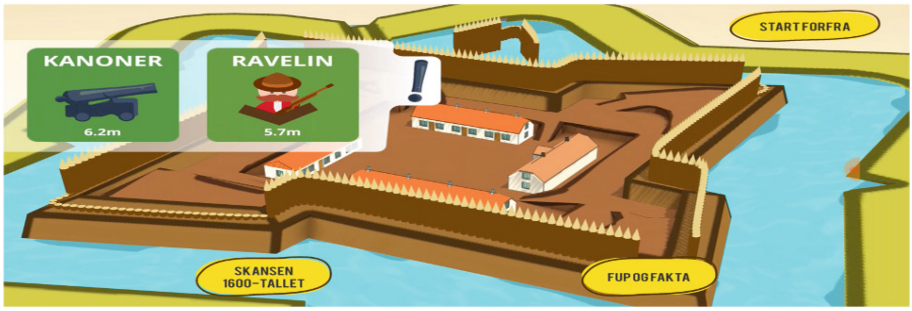

Fig. 3. Screenshot showing the distance indicator, which shows an approximate distance in meters, as well as colors that indicate when the player can interact with and unlock a node.

The gameplay aims to merge game and exhibition, allowing users to explore and reapply knowledge in a constructivist, experiential learning manner, emphasizing the importance of narratives in learning. The game's design and structure in XTR promote a blend of interactive exploration and structured narrative learning called *exploratorium.*

2.5 Locational Narratives for Exhibition Visits

Museum visits epitomize intricate yet enriching encounters, modulated by factors such as time, personal inclinations, and pre-existing knowledge. While the immediate recall of these experiences might elude many visitors, specific stimuli can subsequently rekindle these memories. A potent strategy to bolster such recall and introspection is by juxtaposing a narrative learning framework with the tangible environment of the museum. Narratives, pivotal in the human learning process, offer a scaffolded structure to assimilate experiences [81–84]. Inherently, most visitors are driven by intrinsic motivation, magnetizing towards experiences that resonate with their curiosities. The constructivist learning paradigm characterizes learners as dynamic contributors, prioritizing experiential learning over mere rote memorization. Thus, crafting delineated learning pathways within exhibits can synergize activity, education, and narrative.

Historically, storytelling has been enmeshed in the fabric of cultural institutions. The technological zeitgeist of today empowers museums to venture into the realm of digital narratives. Nevertheless, a prevalent contention is that such technological integrations might fragment the visitor's attention, potentially diluting the primary experience.

XTR's narrative architecture is underpinned by seminal research on mobile narrative trajectories in museums. We delved into the art of narrative framing within both museum and gaming landscapes, identifying congruities in their storytelling matrices. Gleaning insights from seminal texts like "Weaving Location and Narrative for Mobile Guides" [84] and "Story Structures: Building Narrative Trails in Museums" [85], we amalgamated these findings to sculpt XTR's narrative orientations and gameplay content. Our overarching ambition is to fuse traditional museum encounters with the allure of digital narratives, crafting an enthralling exploration game.

The "storycraft" model [86] is an innovative approach that interlaces space, temporality, and narrative. It demarcates varying degrees of interactivity, spanning from rudimentary interface engagements to intricate, dynamic user-curated tales. Through this model, users weave narratives by forging conceptual linkages amongst artifacts.

Several narrative structures useful in digital storytelling are mentioned throughout the literature, useful for implementing narrative structures for interactive storytelling [87]:

- A *tree* has a linear flow with a beginning and multiple separate endpoints. This is most common in text-based work due to its low costs.
- *Nodal*, or a *dead-end structure*, is typically found in action/adventure games and involves numerous alternative paths and dead ends, which may or may not be (but usually are) reversible, generally along a main sequence eventually leading from the beginning of the game to the end [88, 89].
- *Parallel plot structure*, in which different versions of the story are told at the same time, and the reader/viewer can switch between the different parallel versions [81].
- *Modulated*, or the *dynamic labyrinth structure*, provides constellations of interactive choices but only allows access to a new set of possible interactions after the player has experienced different parts of the story [81]. Game levels function in this way.
- *Open structures* in which story elements are associated with different physical places and links between places are open, so the player can wander around discovering different elements of the story [90]. This is the form typical of early adventure games.

A different approach is to have an open structure without a story arc. This is the form typical of simulation-based games, strategy games, and open-world games, such as massively multiplayer online roleplaying games (MMORPGS) [89].

- An *exploratorium* is a linear structure in which the player can pause to explore the surroundings [90]. This story structure provides a structure that allows the player freedom to be inquisitive about objects that suit individual interests and skip anything that is uninteresting, while still progressing the player from beginning to end.

The *exploratorium* structure was a focal point in the design of XTR. It provides a pathway from start to finish, yet simultaneously invites visitors to engage with objects at their individual rhythm. Within the context of museum visits, this model presents an experience that is both guided and liberating. It effectively counteracts "museum fatigue" [91, 92] by empowering visitors to determine their own pace and trajectory. In summation, for the XTR iteration, the exploratorium was selected owing to its harmonious blend of structure and autonomy. This design caters to a visitor's dual inclination towards gaming and acquiring knowledge. The exploratorium model honors visitor predilections and the intrinsic human impulse for exploration, especially in the realm of mobile applications.

3 Experiment Design for an Explorative Exhibition Experience

The study aimed to assess how XTR influences users' explorative behavior and fosters a space for them to engage based on personal interests. It sought to determine users' acceptance of game-guided support, the effectiveness of situated digital storytelling for knowledge acquisition or entertainment, and how the game influenced users' physical exploration. The study adopted the *research in the wild* approach from the HCI tradition, emphasizing real-world testing over controlled lab environments [93–95]. The research was carried out at HMR between October 14th and 24th, 2019.

Prior to the main study, off-site pilot studies assessed the technical aspects of XTR. Issues related to Bluetooth beacons, game content, graphics, and text were addressed. After these modifications, beacons were integrated into the exhibition site. The game was also adjusted based on factors like device type, user concurrency, and weather conditions. XTR's tested version was in Danish, limiting it to Danish-speaking users.

The research methodology combined both qualitative and quantitative data collection methods. Data came from two participant groups: *Alpha* and *Bravo*. Alpha participants were recruited directly at the exhibition, while Bravo participants were recruited both on-site and before their visit, with assistance from the collaborating museum. Alpha had 18 participants (13 females, 5 males) aged between 9 and 65, with 13 being first-time museum visitors. Bravo consisted of 12 first-time visitors (7 males, 5 females) aged between 11 and 42.

The goal was to involve a diverse set of participants, including individuals, families, and couples who might typically visit the exhibition. Previous data from HMR indicated most visitors were from Denmark and Germany, spanning various age groups. For this study, participants encompassed a mix of multi-generational families, couples, and solo visitors. All participants were Danish citizens. The study aimed to represent those who'd engage with the exhibition content based on their genuine interests.

3.1 Process

As mentioned, the test was executed on-site as a study in the wild [93, 95], which is an approach where researchers move from controlled lab-based experiments to the real intended settings. A total of 18 participants were recruited among visitors. We also enlisted an additional 11 participants who were invited to participate in a more detailed study with a concluding interview. The procedure for the recruitment was facilitated by a researcher, where visitors were greeted, and if they agreed to partake in the study, they were briefed about the game and informed about data collection, subsequently signed consent forms, and assisted (if needed) in downloading XTR onto their devices. Following gameplay was a questionnaire. After the participants had filled out the questionnaire, they were free to play the game as they saw fit and explore the exhibition as visitors, but they were instructed to return to the test facilitator when they were finishing up for a follow-up questionnaire. If they were curious, they were allowed to ask questions or redact their consent and opt-out of the test at any given time.

Bravo was interviewed as their final step after the follow-up questionnaire to clarify different aspects of the experience and to gather additional qualitative insights. For both groups, the XTR application ran analytics in the background, logging user interactions and the sequence of beacon unlocks. As such, there were essentially two data collection procedures where one included a more in-depth qualitative probing through interviews.

Methods and Inventories

The study employed mixed methods, utilizing self-reporting questionnaires, a semi-structured interview, and in-app analytics. This allowed tracking of game runtime, crashes, and other metrics. A major tool was the Hexad inventory [96, 97], which identifies player types based on motivations for playing games. Hexad, grounded in self-determination theory [98], classifies players by intrinsic or extrinsic motivational factors [99], thus informing game design decisions. The study used Hexad to discern which game styles would likely resonate with HMR visitors.

The primary data source was the User Experience Questionnaire (UEQ) [100–102], assessing users' subjective impressions of a product's experience. UEQ, a 26-item semantic differential scale, was selected because of its broad application, capturing the overall museum visit experience rather than just the game aspect. It takes about 3–5 min to complete, offering a swift data collection method for gauging product quality. While other specialized tools like the Museum Experience Scale [103] exist, the study opted for a more generalized tool to encompass a wider scope of user experience. Both Alpha and Bravo participant groups followed the same procedure, but Bravo also had a follow-up interview to gain deeper qualitative insights.

Test Protocol

Participants were recruited at the site for XTR playtesting. After signing a consent form, they completed a questionnaire, were briefed about the test, and introduced to the game on their mobile phones. A demo node at the armory building entrance illustrated the game's core mechanism. Participants could then freely engage with the game and other site activities. After their visit, a debriefing took place involving a second questionnaire and feedback session.

The initial questionnaire collected descriptive user data, including demographics and player type psychographics. It contained questions on age, gender, social constellation, and prior experience with location-based games. The player-type section utilized the Hexad inventory, determining player type through a 7-point Likert scale.

During gameplay, the test facilitator observed and documented user interactions through pictures, videos, and notes. The application also captured behavioral data, such as movement patterns, sequence of node unlocks, and time spent at each node.

The post-visit questionnaire gathered feedback on the player experience (PX) and overall quality of the visit. It explored user motivation, digital competencies, and overall experience using the UEQ. Further questions delved into users' gaming habits and the game's influence on their museum visit, including any new discoveries facilitated by XTR.

For Bravo participants, a concluding interview explored the broader visiting experience. It addressed topics like the holistic experience of the automated site with digital media and the impact of XTR on the visit's enlightenment and overall experience, focusing on technology-mediated self-guidance.

3.2 Results

For the study reported here, the UEQ supported by observations and interviews was the source of data used to report on users' experiences of playing the game. While Hexad and analytics provided knowledge about other aspects, they were omitted for the sake of focus in this study: to report on how curiosity and exploration as game design principles for a self-guided system for automated sites affect user experience. The analytics logged within the application were omitted from this study due to data corruption from some play sessions.

These may be revisited at a later point. The study aimed to investigate curiosity and exploration as design principles to facilitate and mediate automated exhibition content. From the test, Hexad provides insight into what motivates a particular player, while the UEQ inventory provides insight into the user experience of playing XTR in an automated site. The following insights from this study are based on three sources of data: questionnaires, observations, and interviews.

XTR User Experience: User Experience Questionnaire

The following details the data from the UEQ, which summarizes the findings from playtesting XTR at the exhibition site. The UEQ consists of 26 questions in the form of a semantic differential, i.e., each item is represented by two terms with opposite meanings. The 26 items provide data for 6 scales: Attractiveness, Perspicuity, Efficiency, Dependability, Stimulation and Novelty. Attractiveness is a pure valence dimension. Perspicuity, Efficiency, and Dependability are pragmatic quality aspects (goal-directed), while Stimulation and Novelty are hedonic quality aspects (noy goal-directed). The order of the terms is randomized per item, i.e., half of the terms of a scale start with the positive term and the other half start with a negative term. A seven-stage scale is used to reduce the central tendency bias for such types of items. An example of an item is: **attractive** × × × × × × × **unattractive**. The items are scaled from –3 to + 3. Thus, represents the most negative answer, 0 a neutral answer, and +3 the most positive answer [101]. Note:

during the analysis of the form data from the UEQ, it was revealed that one question (question 11). This error has consequences for the Dependability score and the question started with a negative term, obstructive as opposed to supportive. This means that the result for dependability is not precise.

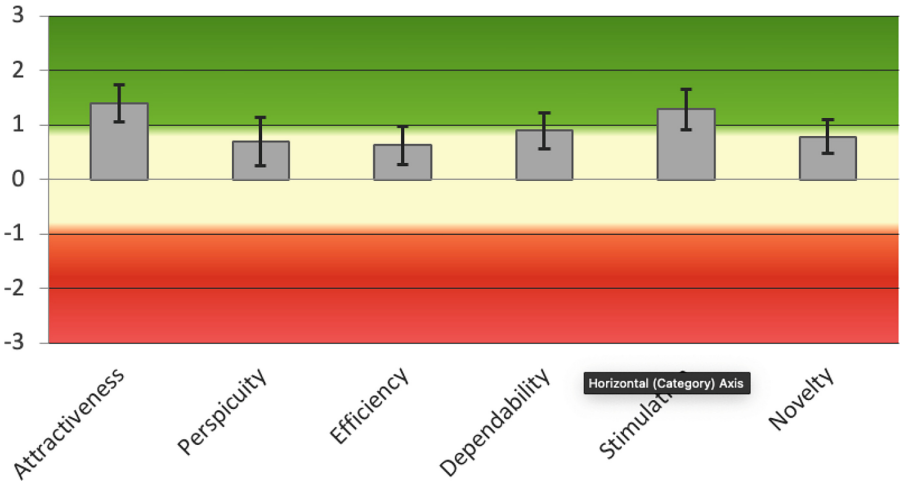

Fig. 4. The scale means from the UEQ test. The standard interpretation of the scale means is that values between –0,8 and 0,8 represent a neutral evaluation of the corresponding scale, values >0,8 represent a positive evaluation and values < –0,8 represent a negative evaluation.

The Alpha participants were recruited on-site from guests who visited the site on their own volition, unlike Bravo participants, who were recruited to participate in a qualitative test of XTR beforehand. In total there were 30 participants who completed the UEQ questionnaire.

Due to the sample size (n = 30) the Cronbach-Alpha coefficients ($\boldsymbol{\alpha = n * r/1 + (n - 1) * r}$, where r is the mean correlation of the items in a scale and n is the number of items in a scale) were not factored into the results presented here. The user experience of XTR from the UEQ test is presented in Fig. 4 as scale means and the benchmarks are reported in the graph in Fig. 5.

The user experience is measured by comparing the results from XTR to a benchmark database containing reports created with UEQ for other products. The benchmark currently contains data from 452 product evaluations with the UEQ, with a total of 20190 participants.

The benchmark classifies the user experience of XTR into five categories (per scale) [101]:

- *Excellent*: in the range of the 10% best results).
- *Good*: 10% of the results in the benchmark data set are better and 75% of the results are worse.
- *Above average*: 25% of the results in the benchmark are better than the result for the evaluated product, 50% of the results are worse.

- *Below average*: 50% of the results in the benchmark are better than the results for the evaluated product, 25% of the results are worse.
- *Bad*: In the range of *the* 25% worst results

Figure 5 shows the benchmark graph from the UEQ for XTR. Table 1 presents the interpretation these values along with a comparison to benchmarks from the UEQ database.

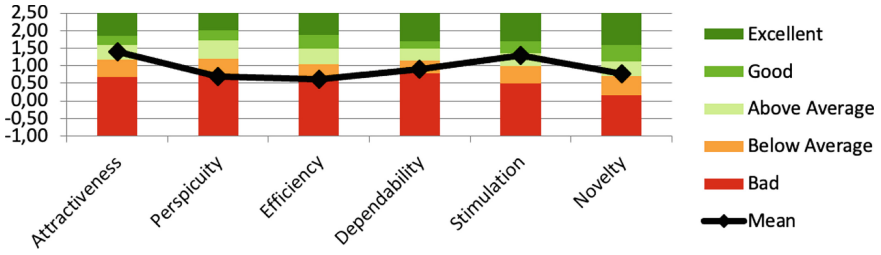

Fig. 5. Benchmark graph for XTR.

The table shows that the overall impression of XTR was above average. However, in terms of perspicuity, i.e., how easy it was to learn, it scores 'bad'. Efficiency and dependability, i.e., can users solve their tasks without unnecessary effort and does the user feel in control of the interaction is below average, while stimulation and novelty, i.e., is it exciting and motivating to use XTR and whether is it perceived by the users as innovative, creative, and interesting to use or not, scored above average.

Table 1. Table with benchmark comparison results and their interpretations along with the scale means

Scale	Mean	Comparison to benchmark	Interpretation
Attractiveness	1,39	Above average	25% of results better, 50% of results worse
Perspicuity	0,69	Bad	In the range of the 25% worst results
Efficiency	0,63	Below Average	50% of results better, 25% of results worse
Dependability	0,89	Below Average	50% of results better, 25% of results worse
Stimulation	1,28	Above Average	25% of results better, 50% of results worse
Novelty	0,78	Above Average	25% of results better, 50% of results worse

From this, it is possible to evaluate that XTR certainly has room for improvement in terms of usability, but from a user experience point of view, it has had a positive effect on the participants from Alpha and Bravo.

XTR User Experience: Conversations and Observations

Users from Bravo tested XTR and participated in a debriefing interview. The interview material was partially transcribed and analyzed qualitatively. Some excerpts were translated from Danish to English by the authors. Table 2 lists Bravo participants, indicating their group details or if they visited solo, and uses anonymized labels to reference quoted interview excerpts.

Table 2. List of participants from Bravo.

Team	Social constellation	Adults	Children (age)	Total
BRAVO	Family 01	2	1	3
	Family 02	2	2	4
	Family 03	1	2	3
	Couple 01	2	0	2
	Solo 01	1	0	1
	Solo 02	1	0	1
	Solo 03	1	0	1

Bravo participants visited the exhibition sporadically, ensuring they experienced the content without pressure. They were observed and interviewed on-site. In the following, the XTR experience is described in three overarching themes articulated to target information specifically for the aim of this study: 1) Self-guidance through mixed reality exploration games; 2) Coherent exhibition experience through digital mediation; and 3) Interest development through curiosity, exploration, and discovery. The first theme is related to the guidance aspect in an automated exhibition site; the second theme is linked to the utility an exploration game like XTR provides users with, in an exhibition that is perceived as a "fragmented experience". The third theme takes aim at the theory posited by Csikszentmihalyi and Hermanson [40] that exhibitions can be designed so that curiosity can serve as a trigger to take hold of the visitor's attention, which could lead to extensive interaction leading to interest development, a key to learning. While the study wasn't focused on measuring "learning", it evaluated how curiosity-driven exploration games might enhance user motivation and interest at automated sites. Additional observations, not aligning with the themes, revealed diverse game-play patterns among users, such as competition or collaboration. These insights hint at the need for game design to accommodate both cooperative and competitive elements.

Self-guidance Through Mixed Reality Exploration Games

After engaging with the exhibition and XTR, participants highlighted key moments from their visit. Both Bravo and Alpha teams initially overlooked the entrance's significance, known as the ravelin—a protective drawbridge of the star fort. However, an XTR node, presenting a virtual reconstruction at the ravelin, illuminated its historical and architectural importance for them. Consider the example below:

"Getting information through play is a lot more fun than just having to go around and read. The game also draws attention to specific things that I can focus my attention toward, instead of not knowing that to examine or look at, in an exhibition that has so many things that are not interesting to me." [SOLO 01].

Participants also noted that XTR made them aware of their physical traversal of the exhibition site and that there would have been areas they would not have discovered or seen, such as the powder chamber, had it not been for the game's guidance through nodes. Consider the following statement:

"Because of the link between the physical and the digital, where the game leads one to certain locations, we entered the powder chamber instead of walking past it." [FAMILY 03, Father].

In the given scenario, the powder chamber door was sometimes closed, leading visitors to assume it was off-limits. When open, the "powder chamber" sign was obscured, causing some visitors to unknowingly enter and leave the chamber. Despite the presence of informative posters, XTR's outdoor information was praised for enhancing exploration. Notably, many visitors missed the significant whale vertebra exhibit at the entrance, only realizing its presence through XTR. For some, the game even lengthened their museum visit:

"If not for the game, we would have just walked around and left after a short while, but with the game, there were objectives in the game that I wanted to solve." [FAMILY 01, Mother].

Participants highlighted content they would've overlooked, like the unusual tale of a priest who concealed a gun during WWII. This story was spotlighted by XTR's quiz, prompting visitors to revisit and absorb it, describing it as "funny" and "peculiar." On the social aspect, users felt that XTR fostered a collective play experience among groups, enhancing social bonding and guiding their visit. Some even engaged in competitive gameplay within their groups through XTR. Consider the example below:

"We wouldn't have moved around outside without the motivation the game provided. We would probably have stood at a distance and viewed the rampart instead. It was cool to wander around the ramparts." [FAMILY 03, Father].

Coherent Exhibition Experience Through Digital Mediation

One participant stated, "The museum exhibition feels like a moebius strip without an app like this" [SOLO 01]. Many from the Bravo group felt the exhibition was too "compact" and "confusing", lacking coherent themes. The abundance of reading material discouraged some visitors: "Playing made me active and investigative instead of simply walking around. I didn't even want to read any of the signs; there was too much to read." [FAMILY 01, man]. However, the game provided structure, enhancing the overall exhibition experience: "The exhibition was a mess with a lot of things… the game supported the journey through the exhibition" [FAMILY 03, Father].

Interest Development Through Curiosity, Exploration, and Discovery.

One visitor noted, "Usually, I stand at a distance from the exhibits, but the game made me have to walk in close proximity to certain things, which made me look closer than I would have" [FAMILY 01, Mother]. Another commented, "Usually, I find museum visits boring, but playing a game flips the visiting experience upside down." [Family 01, Father]. The game's design encouraged visitors to engage more deeply with exhibits and information: "It was great that XTR made me focus my attention on specific information, and that I had to activate the knowledge I acquired in the game." [SOLO 03].

However, some criticized XTR for making them focus too much on screens instead of landmarks and suggested improvement like a notification system to guide them. Despite such feedback, many appreciated the game's physical-virtual integration, allowing for a

unique experience, like reconstructing the historical redoubt. Notably, terms like "ravelin" became clearer through XTR's visual references: "The word "ravelin" is unfamiliar to me. Without the references provided by XTR, I would never have understood its significance." [SOLO 01]. Participants felt more invested and curious, with the game enhancing their understanding and enjoyment of the exhibition.

4 Discussion and Limitations

The development of XTR was informed by prior studies on design and technical implementation for crafting mobile guides tailored to exhibitions. This research surpasses previous endeavors by focusing on designing for automated sites, emphasizing curiosity, exploration, and discovery as primary design principles. Such design principles facilitate probing the following research questions: How can a game-guided, exploratory system assist users in automated sites? Additionally, how might a game be constructed to foster an environment conducive to individual interests?

Initially, we postulated that the fusion of mobile media technologies and mixed-reality games might be instrumental for self-navigation within automated exhibitions. Our primary focus revolved around the utility of games to engender exploratory behavior, thereby igniting curiosity and sustaining interest. This could potentially harmonize the dual objectives of enlightenment and experience while aiding users in navigating automated exhibition sites. Consequently, we embarked on a journey to discern how mobile devices can be intermediaries for exploration and self-guided automation. The objective was to scrutinize the feasibility of digital adventure games in harmonizing the often-conflicting expectations of automated exhibitions.

To address the primary research question, this study pivoted around the conceptualization of digitally mediated experiences tailored for automated exhibitions. Further complicating the design process is the existing dichotomy in the museum narrative: should museums primarily educate or entertain? Our response was the design of a mixed-reality mobile game, drawing elements from adventure games, thus converting exhibition sites into knowledge-rich playgrounds. This transformative approach champions the user's motivations over the museum's intent. Feedback from XTR play testers corroborated that the game augmented their museum experience, offering navigational assistance, promoting exploration, and revealing hitherto undiscovered facets of the exhibit. Such positive responses to the game-guided exploration suggest future museumgoers might readily adopt this model. This observation harmonizes with prior research, allowing us to delineate the game design elements that resonate within this context.

Our secondary research question delved deeper into how games can foster environments reflecting individual interests. Our analysis unveiled that XTR adeptly facilitated shared experiences, creating a framework wherein users could tailor their journey based on their primary motivations for the visit. The marriage of the virtual layer with the physical realm demonstrated a potent mechanism to educate and enlighten users. A recurrent observation was the users' appreciation for the digital visualization of the redoubt as they navigated its physical counterpart. The term "interests" would perhaps be a more accurate reflection than "personal interests," as many users identified shared interests rather

than individual pursuits. This dimension of shared experiences remains an uncharted territory deserving further exploration.

Our insights align with existing literature, offering a deeper understanding of the design intricacies pivotal for interactive mobile systems tailored for self-guided exhibition scenarios. The primary takeaway underscores the imperative for a seamless integration of the digital overlay with the physical exhibition layout. This synergy should be at the forefront of system design, ensuring efficient navigational support and enticing users to explore lesser-trodden paths. Furthermore, the presentational sequence should grant users autonomy in their exploration. XTR's demonstration highlighted the liberty it offered users in charting their unique courses.

A secondary design insight revolves around the cohesion introduced by the digital layer. Prior to XTR's inception, visitors often reported a lack of thematic coherence in the HMR. XTR's introduction offered a more integrated experience, bridging the gap between gaming and museum exploration, which received commendation from users. Ensuring coherence thus emerges as an indispensable component, especially for exhibitions perceived as disjointed.

Lastly, the motivational facet of XTR, embedded in its design to spark curiosity, facilitate exploration, and catalyze discovery, merits attention. While achieving a balance between enlightenment and experience within a game framework poses challenges, XTR's design illustrated that users were indeed prompted to explore, discover hidden gems, and accrue knowledge. This suggests that designing exploration games with these principles at the forefront, especially in the context of self-guidance, is a promising avenue.

4.1 Design Tactics for Exploration Games

Here, the design insights are summarized as design tactics proven to be important to consider by this study as guiding design principles: 1) Link the digital game layer and the physical layout of the exhibition with the freedom to choose one's own path; 2) A coherent exhibition experience should link activities in the digitally mediated layer with the physical exhibition site and its exhibits; 3) Curiosity, exploration, and discovery for interest development and guidance, manifested through (adventure) game design and mechanics, must be the core design principals.

4.2 Limitations

Curiosity, undeniably integral to the act of play, thrives on novelty, whether in the form of sensory indulgence or cognitive challenges encompassing problems, strategies, or narratives. Expecting a game to retain its appeal over time without incorporating design elements fostering novelty would be a misjudgment. Games devoid of mechanisms to perpetuate this sense of novelty often witness a fleeting spike in motivation, a phenomenon colloquially termed the "novelty effect" [41, 68]. XTR is exempted from this critique, given its objective is to enhance the user experience during a single exhibition visit rather than repeated engagements. If XTR's remit were to span multiple visits, it would necessitate extrinsic motivators beyond mere curiosity and interest. One promising strategy to foster replayability lies in emergent game dynamics; these dynamics ensure that even

repeated interactions with familiar content yield fresh experiences. Feedback from user trials highlighted participants' keenness to delve deeper into the system's exploration capacities. Thus, a compelling design avenue lies in amplifying the scope for variability and unique experiences in consecutive or extended game interactions.

Post the culmination of this study, exploration as a core game mechanic was spotlighted in subsequent research, encapsulated by the "exploration-exploitation dilemma" [67]. This pertains to the act of information collection and leveraging accumulated knowledge to reap rewards. XTR's reward mechanism centers on information discovery, which could potentially be its primary allure. Introducing random exploration combined with reward mechanisms via a "systematic switching" approach, which promotes uncertainty-driven exploration, merits further exploration [67].

This study did not harness user behavior models to scrutinize patterns in user movement during gameplay. However, prior studies have delineated user archetypes such as *ant*, *butterfly*, *fish*, and *grasshopper* based on observational insights in museum settings [56]. These archetypes could potentially be harnessed as analytical tools in subsequent research. An intriguing proposition is discerning whether user behavior exhibits shifts when engaged with or without an exploration game like XTR. The *explorer* persona, as defined by Falk and Dierking [104], was pivotal during the nascent stages of this research, underscoring the importance of exploration in game design. Further iterations could potentially integrate diverse user personas to cultivate a more holistic user experience.

Reconciling the dichotomy between user autonomy in exploration and system-driven directionality emerged as a notable challenge. Although guiding users necessitates some level of system-driven direction, this seemingly contradicts the principle of granting users the freedom to follow their intrinsic interests. This tension parallels constraints observed in linear narratives. Our attempt to mitigate this tension led us to the exploratorium model. Beyond the systematic switching strategy, existing literature delineates the distinction between emergent goals and imposed objectives. Rozendaal et al. [105] associate emergent goals with user-driven creative and improvisational actions, an aspect worth considering in future research endeavors to inform game design iterations.

On a technical front, challenges arose with Bluetooth beacons for location tracking. While these beacons can pinpoint a user's location, they often miss contextual nuances. For instance, a user might be proximal to an exhibit but might be oriented away from it. Challenges were further exacerbated by inconsistent tracking performance across different device types, with notable discrepancies observed between iOS and Android devices.

5 Conclusion

The primary goal of this study was to delve into curiosity and exploration as foundational tenets for designing digitally mediated experiences tailored for automated venues, leveraging cutting-edge mobile technologies. The insights gleaned from this research pave the way for the design and deployment of analogous computer-mediated technologies in automated exhibitions to bolster the museum-goer's experience. The term "support" encompasses scenarios wherein exhibitions face hurdles in transmitting their

content. This may be attributed to a disjointed exhibition design that disorients visitors, or challenges in navigation, or perhaps a discord between the museum's intended visitor experience and the actual motivations or intentions of the visitor.

In our research, we posited that the amalgamation of mobile media technologies and mixed reality games holds promise for self-navigation in automated exhibits. The feedback was overwhelmingly favorable toward XTR, an explorative game. Participants recurrently expressed that the game enriched their visit, promoting proactive engagement and assisting with navigation. Crucially, XTR conferred a sense of continuity to what might otherwise feel like a fragmented exhibition landscape. A salient revelation from our study underscores the pivotal role of cultivating visitor interest. Although many participants were not initially drawn to the exhibit out of personal intrigue, engagement with XTR uncovered elements they found captivating. Hence, participants manifested a receptivity to exploration games, irrespective of whether they embarked on the museum journey solo or in groups. Crafting an environment conducive to exploration has the potency to ignite curiosity, subsequently kindling genuine interest. Games can be intricately woven to perpetuate this engagement and amplify this burgeoning interest via active user participation. Yet, it's essential that these games allow visitors the latitude to immerse themselves in any artifact they deem intriguing, facilitating contemplation rather than herding them toward a prespecified endpoint. Consequently, the value proposition of exploration games, especially in reinforcing user experiences in automated settings, was underscored.

XTR was envisioned as a digital aide to assist visitors with navigation, offer insights akin to a human guide, and extend this support to groups, acknowledging that many choose to experience exhibits collectively. Beyond the dimension of navigational assistance, the transmission of information was also at the forefront of our exploration. The multifaceted challenge bifurcated into the realm of self-navigation in automated environs and harmonizing enlightenment with experiential depth. Addressing this conundrum, XTR ingeniously interweaves game design facets, buttressed by psychological and cognitive paradigms pertaining to motivation drawn from adventure games, seamlessly into the exhibit milieu. Drawing from our empirical research at the HMR, XTR reimagines exhibitions as fertile grounds for experimentation, the cultivation of unique interests, and the application of newfound insights beyond the confines of these knowledge sanctuaries to real-world scenarios. This elevates mundane routines into rich experiential narratives ripe for discovery. When a player immerses themselves in a game within an exhibit, the demarcation between playing and visiting becomes increasingly blurred. Echoing Dewey's earlier [106] sentiments, irrespective of its enlightening or experiential quality, any event that deviates from the mundane rhythm of life is an experience in itself.

In essence, our research underscores the potential of exploration games to facilitate visitor engagement within automated exhibition spaces. Mobile adventure games can be harnessed to accentuate the traits of curiosity, exploration, and discovery, all pivotal for self-navigation and kindling personal interests. Through the meticulous design, realization, and assessment of XTR, we have spotlighted three pivotal design strategies for digitally mediated solutions in analogous contexts. Future endeavors should escalate in scope, embracing a diverse methodology and augmenting the pool of participants and

exhibition locales. This would also provide an avenue to discern the viability and inherent challenges of deploying exploration games across a spectrum of exhibits, spanning from art to natural history.

In conclusion, with XTR, we unfurl a novel paradigm wherein the act of playing games can transform visitors in an exhibition site into explorers in a knowledge playground.

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