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Research Paper

From Personalization Potential to Interactive Museum Experiences

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Abstract. Museums are increasingly adopting interactive, adaptive, and data-driven technologies, yet their conceptual integration into exhibition design often remains underexamined. Visitor behavior follows recurrent patterns shaped by personal, physical, and social factors, calling for approaches that balance technological potential with curatorial control. This paper presents a scenario-based approach to interactive museum systems, distinguishing interactivity, adaptivity, and personalization with personalization as the core design principle. The approach uses behavioral typologies to define scenario branching, eliminating the need for real-time individual user profiling. A mixed conceptual and design-oriented methodology synthesizes museum studies, interaction design, and learning models to derive visitor typologies. These typologies approximate diverse behaviors into finite pattern types. Interactivity is conceptualized as trigger points embedded in the exhibition narrative, activating predefined scenario branches. The framework is implemented in Écho d'Azur, an interactive installation combining audiovisual media with machine-learning-based emotion recognition. Results show that scenario-based personalization enables controlled, multidimensional narrative structures, shifting from linear storytelling. Attention management is supported through spatial layout, audiovisual components, and interaction points based on behavioral patterns. Real-time adaptation is contrasted with design-time personalization, reducing technical complexity and ethical concerns while maintaining curatorial coherence. Thus, scenario-based personalization offers a viable framework for interactive museum design, supporting diverse visitor behaviors without continuous real-time adaptation.

Keywords: Interactive Systems, Scenario-Based Personalization, Human–Computer Interaction, Behavioral Modeling, Audiovisual Interfaces, Recommendation Systems, Museum Technologies

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1 Introduction

Technological innovation in museums has been advancing at a pace that exceeds the development of frameworks for interpreting, evaluating, and meaningfully integrating these technologies into curatorial practice. Therefore, in many cases, the adoption of digital tools occurs in response to external trends rather than as part of a coherent strategy. This creates a structural gap: while technologies enable unprecedented modes of interaction, immersion, and data-driven decision-making, the sector still lacks a consistent conceptual model that would help determine how and when these tools should be applied and what types of experiences they are designed to support.

The terms interactivity, adaptivity, and personalization are often used as synonyms. However, they refer to different mechanisms. Interactivity arises due to visitors' inputs (some kind of interaction with museum's space). While adaptivity refers to the exhibition's capability of changing the outputs (light, sound in the space, etc.), which are based on real-time data (e.g. number of visitors). Personalization is actually a kind of adaptation of the exhibit to the visitor. Predictive and recommendation models collect data about choices of each visitor and, based on that, propose the next plot twist. Thus, tools based on these three mechanisms may be present in exhibitions' design, but while these terms are not well explained, their dramaturgical purpose remains undefined, technological choices stay disconnected from the visitor's needs.

At the same time, visitor behavior in museums is shaped by well-established personal, physical, and social contexts, as demonstrated in multiple studies. People follow various trajectories, they have different levels of engagement and cognitive rhythms. These differences indicate that no single pathway or narrative can be optimal for all audiences. Therefore a technological approach that simply adds some digital tools without considering behavioral segmentation remains insufficient.

This study examines technologies across three stages in the museum development of digital tools: interactivity, adaptivity, and personalization. The aim of the study is to analyze how these approaches are implemented in practice and how they shape visitor experience. The study advances the hypothesis that personalization, when properly conceptualized, provides the key enabling mechanism for interactive museum systems, enabling the translation of computational potential into situated visitor experiences.

This paper reconceptualizes three earlier studies on interactive exhibition systems by Rybakova [2026], Chizhik [2026], and Cokrlic [2026]. These studies analyzed emotion-reactive installations, projection and audiovisual technologies, and personalization in museum spaces. In the current study the results of these works are integrated into a unified system-level framework that shifts the focus from real-time individual adaptation to design-time personalization based on visitor typologies and narrative scenarios.

The remainder of the article is organized as follows. First, the possibilities of identifying types of museum visitors are analyzed. As a result, key types were fixed with bound to exhibition contexts. Their identified behavioral characteristics are described as approximate models. It then analyzes selected case studies that employ interactivity, adaptivity, and personalization, with attention to the techniques and algorithms underlying these approaches. Finally, the article presents the authors' own experience with interactive systems, discussing the application in the personalization of the museum experience.

2 Visitor types and contexts of museum behavior

This study proposes an approach in which visitor typology plays a key role in designing museum experiences. According to Weil [2002], the shift of the museum "from being for something towards being for someone", is the central point of New Museology articulated by Vergo [1989]. But it is difficult to incorporate it without a clear methodological basis. Efforts to adapt exhibition spaces to visitors' needs and interests may obscure the fact that no "typical visitor" exists in practice. As it is underlined by Wright [1989], "*there is no single level which can be expected and then addressed*", as people come to the museum with different prior knowledge, interest, expectations, and habits. With such an outlook the idea of making a museum into "a space for all of us" seems quite utopian. This tension suggests the need for an approach that shifts the focus from individual differences to recurrent patterns of visitor behavior.

This aligns with a broader shift in museum and interaction design research, where the focus moves to identifying patterns of engagement, as discussed by Falk and Dierking [1992]. As a result, visitor types are used as analytical tools that reduce complexity while preserving behavioral diversity. What influences the way visitor types behave in museums? Generally, museum experience is shaped by three interrelated factors: personal, physical, and social.

The physical dimension of a museum visit plays an important part in shaping visitor behavior. This includes the museum's spatial layout, exhibition design and direction signs. These factors shape a museum's atmosphere, which may be perceived as comfortable and understandable or as confusing. According to Piancatelli, Massi, and Piancatelli *et al.* [2021], lighting and spatial design affect both the satisfaction of the visitor in the moment of visit and the wish of the visitor to come again or recommend a museum to others. Another factor (social) that influences the visit is whether a person is coming to the museum alone, with peers or with a family group, this directly influences the time spent on the exhibition and by each exhibit in particular. For example, there is a drastic difference between a group of adults and a family, where children tend to determine the amount of time spent in a room, as well as the level of engagement, as observed by Lakota [1975].

Recent research shows that introducing social feedback (e.g. sharing other visitors' reactions) can enrich the experience, as shown by Yi *et al.* [2022]. This approach was explored in the project Monuments for a Departed Future (Museum of Yugoslavia, 2017), where social feedback became a part of visitor experience via QR-based interaction, as described by Ryding [2024]. The museum created a sort of a dialogue between visitors, who were proposed to answer the open questions and, at the same time, were able to see anonymous answers from other visitors.

The physical and social factors do not translate directly into behavior on their own. Rather, they shape the conditions under which individual knowledge and intentions are expressed as specific patterns of behavior. In this sense, personal factor refers to how individual dispositions are actualized as situated behavior within a specific spatial and social environment. Thus, besides the individual knowledge and "agenda" of a visitor, there are common behavioral styles found in a museum space, traditionally coded with animal-based styles. This typology has four types: ant, butterfly, grasshopper and stroller.

Such types were defined by Véron and Levasseur [1989]. A type of visitor called "the ant" tends to carefully observe almost all exhibits and usually follows a standard path, while "the butterfly" stops by few attractive points and is guided mainly by how the exhibits are located inside the rooms, as described by Kuflik *et al.* [2012]. Another pattern is "the fish": these visitors engage with the exhibition on a more overview level. They move along spatial axes of the exhibition space. The "grasshopper", in turn, is characterized by selective and discontinuous movement. It jumps between distant exhibits that match his specific interests while ignoring most of the content. The fifth, and the last in this typology is "the stroller", who has no fixed route, he moves slowly and doesn't have a strong goal while visiting exhibition. Despite the fact that the typology was written several decades ago, modern research shows more or less the same results.

For example, in the study by Rhee *et al.* [2025], the level of visitor engagement was detected when using different options of digital services. The experiment showed that different forms of interaction produce distinct movement and engagement patterns. This fact indicates that visitor behavior follows structured patterns at a group level. Spatial analytics with computer vision models further demonstrated that museum visitors can be clustered and that an individual path is not personal indeed, but similar to the entire cluster of this type.

Taken together, the physical and social factors structure knowledge and intentions of individuals into observable patterns of behavior. This allows the visitor's variety to be approached not as an open set of unknown, but as a limited number of behavioral types with specific manifestations. These types can be mapped onto a finite set of narrative trajectories within the exhibition. Which aligns with the logic of recommendation systems, where predefined options are matched to recurring behavioral patterns rather than to individual profiles.

3 Interactivity and Adaptivity

Interactive museum installations vary in form and function. They engage the senses and create a feeling of being inside the story of the exhibition. Touch screens, motion-controlled projections, VR and AR, 360-degree installations, and holograms are the main interactive formats. Traditional displays and dioramas present content in a fixed form, thus use passive viewing. In contrast, interactive installations are built around active visitor participation. Interaction is the main part of how the content is experienced.

For example, projection-based media can change in response to a viewer's movements, creating the effect of "living" images, as described by De Morais Sarmento [2024]. The startup Ask Mona [2025] can also be used as a case of interactive visitor engagement. The audio guide based on LLM (Large Language Models) was developed. This tool is currently being used at the National Museum of Fine Arts of Quebec, providing real-time responses to visitors' questions. Using this technology in museums leads to significant changes in how visitors interact with art exhibitions. It uses AI to create a more personalized, interactive educational experience and as a result, increase its impact.

Adaptivity refers to the ability of an exhibit to change in real-time in response to the actions of the visitor. This could mean altering the narrative presented depending on what an individual chose while passing through the exhibition space or dynamically adjusting the audio guide to focus on aspects that engage the visitor the most. This approach implies the presence of 2-3 or many scenarios for the development of the story embedded in the exhibition.

A large area of attempts to engage visitor experience is represented by robotics, namely robots designed to function as tour guides in museums. Without a doubt, it is a complicated task, and, as Hellou *et al*. [2022] show, to be able to actively adapt to circumstances a robot's skills should include social navigation (moving autonomously through a space and guiding a group of people), perception of human emotions and attention, speech, gestures, and behavior perception and generation. Among the innovations are those connected to human emotion detection and tracking, because the perceived interest can be used to engage the visitors with this or other artwork.

For example, the ASIMO robot developed by Iio *et al*. [2020] works within a strategy called "speak-and-retreat": the robot comes closer to a visitor and pronounces one segment of the utterances for an explanation (speak phase). Then it steps back waiting for a chance to offer its next explanation (retreat phase) without giving up a conversational turn. This gives the visitors time to observe the exhibit. The robot can offer a great amount of knowledge to interested guests, and the number of provided explanations will be personalized depending on their interest.

Another example is a mobile robot called Robovie-R Ver.3 developed by Yousuf *et al*. [2013]. The crew came up with a strategy that would analyze whether the visitors' attention was directed towards an artwork or the robot itself. If the visitors' faces and bodies are pointed in the direction of an exhibit for five seconds, the robot states that they are interested in it and offers some explanations about the piece. If, on the other hand, the visitors are oriented towards the robot itself, it suggests commenting on the nearest exhibit to them. To track the body orientation, the authors employed a sensor pole with two laser sensors: one at the ankle level and one on the top. These two overviewed cases provide valuable examples of personalization through interactivity and adaptability technologies shaped by on spot feedback and active interest.

The next logical step of personalization strategies would be an algorithm that would take into account both a user's profile and their situational response to exhibits. The closest developments in this direction have been made by creators of audio guides. For instance, the "Hippie's" model is based on interaction with content, as proposed by Oppermann and Specht [2000]. While another guide, "HyperAudio", evaluates both the explicit information (user action on mobile platform) and implicit input (user's position in a room) to adapt narration, as described by Petrelli and Not [2005].

Essentially, these methods of personalization come the closest to the functioning principle of social media algorithms, which generate recommendations based on two key factors: interaction data (such as viewing duration and engagement signifiers like comments, likes, and shares) and accumulated information about the user's preferences, as outlined by Kim [2017].

From the above, it follows that designing an interactive space with adaptive features requires careful planning of the interaction script, including how visitors will engage with the system, the sequence of actions they will take, and the feedback they will receive. Ideally, the interaction scenario is closely intertwined with the narrative. At this stage of experience design, the museum can introduce a limited set of personalized scripts aligned with different visitor typologies. Any form of adaptive system presupposes that visitor behavior can be translated into measurable traits that the system can detect, process, and act upon, as demonstrated by Cerpentier et al. [2023]. Visitor behavior emerges from multiple interacting factors and has measurable behavioral traits. As it is shown in the article "Analyzing Visitor Behavior to Enhance Personalized Experiences" by Ivanov and Velkova [2025], the traits of visitor behavior most researched in contemporary museology are the following:

1. Attention span,
2. Content preferences,
3. Dwell time,
4. Emotional response,
5. Exhibit interest,
6. Group dynamics,
7. Interactive engagement,
8. Learning patterns,
9. Movement patterns,
10. Physical positioning,
11. Social interaction,
12. Visitor flow.

Among the traits of visitor behavior, the most studied ones are interactive engagement and movement patterns, which constitute the research objective of 72.7% out of all reviewed studies. These traits provide an empirical basis for adapting exhibition content to the visitor's situation, using real-time data on location, actions, and dwell time. The most referred to technology in reaching such dynamic adaptivity is location tracking systems combined with AI-driven algorithms. However, such an approach towards smart museums causes multiple challenges and problems: from the complexity of combining multiple disciplines under one strategy, to the difficulties of financing and physically implementing the technology in the frame of an already existing museum space. This means, rather than relying on continuous real-time adaptation, the proposed approach places personalization at the core of experience design. While adaptive systems operate on measurable behavioral traits during the visit, personalization allows these same traits to be used offline, at the stage of scenario design.

In other words, there is a change in the point of view on the problem: rather than executing system logic primarily in real time, this approach emphasizes the design of logic during experience planning (real time → design time). Thus, behavioral data are aggregated and typologized, and serve not as triggers for immediate system responses, but as inputs for constructing a limited set of experience scenarios. This shift allows it to operate without the technical and ethical constraints. Within this framework, interactivity functions as a system of trigger points embedded in the narrative. These interaction points serve as moments of choice and feedback, where the system can branch between preconfigured narrative paths. In this sense, interactivity provides the operational mechanism through which personalization is enacted. Thus, personalization in the logic of this study relies on the same behavioral traits commonly used in adaptive systems, but operates on them in an aggregated and typologized form, and primarily at the stage of scenario design rather than real-time execution.

This shift requires a reconsideration of the behavioral traits listed above. Rather than treating all traits as inputs for real-time system response, the proposed model differentiates between traits that form scenario design (narrative structure), traits that function as interaction triggers (interactivity elements of an exhibition), and traits characteristic of fully adaptive systems. At the level of design-time personalization, the most important traits are stable ones that can be grouped and linked to recurring behavior patterns. This is the process of typologization: it encompasses content preferences, movement patterns, dwell time understood as a characteristic of a visitor type rather than a momentary signal, learning patterns reflecting different cognitive rhythms, and exhibit interest considered in an aggregated form. Together, these traits form the basis for preconfiguring narrative scenarios.

Interactive engagement, attention span, and emotional response are not treated as variables for continuous adaptation, nor do they require precise sensing. They function as interaction triggers embedded in the narrative. Initiating an interaction, requesting additional information, or choosing to continue along a particular are the inputs from visitors that activate points of narrative bifurcation, enabling the system to branch between predefined lines of scenarios. While factors such as physical positioning, visitor flow, and real-time group dynamics are effective in the fully adaptive systems, they are not central to the methodological logic proposed in this study.

The remaining question concerns which aspects of the museum experience are subject to personalization within the proposed framework. These can include content delivery, interface configuration, or suggested routes through the exhibition. Organizing these elements into a coherent visitor journey requires an algorithmic logic capable of selecting the next narrative step based on predefined scenarios. At this point, the logic of recommendation systems moves beyond a conceptual analogy and can be understood as an algorithmic and technical structure for managing narrative progression.

4 Personalization as a System-Level Approach

Thus, personalization can be understood as a system-level way of organizing the visitor experience. Instead of adapting to each individual in detail, it works by arranging narrative paths based on common behavioral patterns and predefined scenarios. Personalization tools function as narrative triggers that guide individuals' attention. This process forms visitors' movement through the exhibition. For example, they can help refocus attention when visitors become tired or overwhelmed with information. In this sense, content is dynamically optimized within the exhibition narrative – not through real-time reactions, but through the planned selection and sequencing of narrative elements. While personalization is often implemented through machine-learning techniques, the relevance of such approaches for the present study lies not in the specific models employed, but in the underlying algorithmic logic. The following examples illustrate how behavioral data and user information can be structured to support recommendation-based narrative decisions, rather than serving as templates for large-scale data collection or real-time adaptation.

The first example is a study by Puspasari *et al.* [2022] that developed an app for virtual visits to museums during the Covid-19 pandemic. The practical part was conducted on a singular museum that struggled because of the decrease of the number of visits, Sultan Mahmud Badaruddin II museum in Palembang, Indonesia. The developed app is built to mimic a physical visit: the user can see a 360-degree view of every room and move through them consecutively. Before starting the virtual visit, the user has to input information in their profile, which helps the app to identify a number of variables: age, gender, origin, education, occupation, and motivation for visit. The app then processes this information using machine learning – the KNN (k-nearest neighbors) was chosen as the optimal model for the task. As the analysis of the user profile is complete, a Smart Guide feature menu makes a recommendation as to which room is expected to be the most interesting for the user as the start of the virtual visit. This case is relevant in demonstrating how recommendation logic can be used to select an initial narrative trajectory based on aggregated user characteristics. At the same time, the extensive amount of personal data required highlights the limitations of profile-based personalization and motivates the use of typologized behavioral patterns instead.

Another museum app was developed by Torres-Ruiz *et al.* [2020]. The strategy of their work is similar to the previously described case, but their goal is to enhance a physical, rather than a virtual, museum visit. The recommendation system was introduced for museums in Mexico City. To construct recommendations, data were collected from multiple sources. Museum social media pages and their websites were analyzed using web scraping tools. This data helped to classify museums according to content and visitor profiles. In selected museum rooms, sensors were installed to track visitors' location and the time they spent near exhibits. These data were organized into an ontology and processed using semantic analysis. Compared to the previous case, a smaller set of user variables was considered. The combined dataset was then processed using machine learning over context vectors and user profiles. Visitor opinions extracted from comment sections were categorized as positive or negative, while beacon-based data were classified into significant and non-popular elements. On this basis, the system generated a suggested route through the exhibition. This case is particularly relevant for demonstrating how recommendation logic can be used to orchestrate visitor trajectories across different stages of the museum experience. At the same time, the need for extensive data collection and continuous sensing shows the technical complexity of these approaches and motivates simpler personalization strategies based on aggregated behavior and predefined scenarios.

Taken together, these examples illustrate that while many personalization techniques borrow from social media recommendation algorithms, their role in museum contexts is fundamentally different. Rather than maximizing engagement, recommendation logic is used to manage narrative coherence and visitor orientation within a predefined experiential structure. Personalization can be formalized as a combination of preference modeling, scenario-based adjustment, and algorithmic selection of narrative trajectories. In this sense, personalization operates at a higher systemic level than adaptivity: rather than reacting to immediate user behavior, it anticipates possible trajectories of experience within a structured narrative framework.

5 System-level Framework

This section summarizes the proposed framework as a unified system. The approach is based on a shift from real-time adaptation to design-time scenario construction. Figure 1 presents the summary diagram of the approach.

In the *design-time*, visitor behavior is represented through typologies. These typologies are derived from recurring behavioral patterns such as movement, engagement, and content preferences.

Based on these typologies, a limited set of narrative scenarios is constructed. Each scenario defines a possible trajectory of the visitor experience.

During the visit *runtime*, interactivity functions as a system of trigger points. These triggers are activated by visitor actions such as interaction with objects, attention shifts, or engagement with content.

Each trigger activates a transition between predefined scenario branches. In this sense, the system does not generate new content, but selects from a constrained set of narrative options.

Personalization operates at the level of scenario selection and sequencing. Interactivity provides the input, and the system maps it to the closest predefined trajectory. This structure allows the system to maintain narrative coherence while supporting diverse visitor behaviors without continuous real-time adaptation.

6 Audiovisual Media as Narrative and Attention-Control Mechanisms

Within personalized and scenario-based exhibition design, video and audio components play a central role as narrative carriers and attention-directing mechanisms. Audiovisual media can be used not only to convey information, but to structure, unify, and modulate the visitor's experience across different stages of the exhibition.

The traveling exhibition The Changing Face of Women's Health was presented alongside a visitor survey, as reported by Serrell [2002]. The exhibition was largely based on video material and relied on first-person narratives, allowing women to communicate personal and emotional aspects of health-related topics. Its primary aim was to enable women to "speak for themselves" and to convey emotional depth through personal storytelling. The exhibition consisted of five main videos addressing five different aspects of women's health.

The accompanying survey was conducted across three exhibition venues – the Maryland Science Center, the New York Hall of Science, and the Oregon Museum of Science and Industry – and revealed several key findings. Attracting power was measured and has shown 12-35% (percent of visitors that stopped to watch the videos). As the survey showed, people felt more compassion since they saw real women talking about their health/profession challenges. Holding power was measured and has shown 0.03-0.50 (how much of the video people watched, 1.0 is max value). In addition, the videos demonstrated strong memorability. Visitors mentioned them in exit interviews and follow-up surveys two months later. Videos featuring strong personal narratives showed higher engagement levels than those with a more informational focus.

Additional insights were provided by a survey conducted at The Potteries Museum & Art Gallery, which examined visitor engagement with video installations and interactive exhibits. The results indicated variations in preferred engagement time. Approximately 30% of visitors said that they are willing to spend only 1-5 minutes on installation and the same number of visitors is encouraged to spend 5-15 minutes, moreover 30% said that the time really depends on the type of the exhibit or installation. Additionally, the feedback regarding the type of video was gathered showing that 20% of respondents believed that video is more engaging when it features dramatized storytelling rather than a documentary style and 20% preferred short interactive video content on mobile devices rather than large public screens (in order to reduce noise in the gallery).

Taken together, these findings highlight the growing importance of video (and video projections) in museum contexts. At the same time, the purpose of the video projection had to be defined before developing the project in order to create balance between projection and the subject of the exhibition. This will help to correctly place accents and emphasize the right part of the narrative, not losing the concept of an exhibition. This statement can be easily extended to the multimedia in general. Multimedia elements can easily take all the attention at the exhibition space, not letting visitors get the main thought of the project. Therefore careful placement and narrative calibration are essential to ensure that audiovisual media

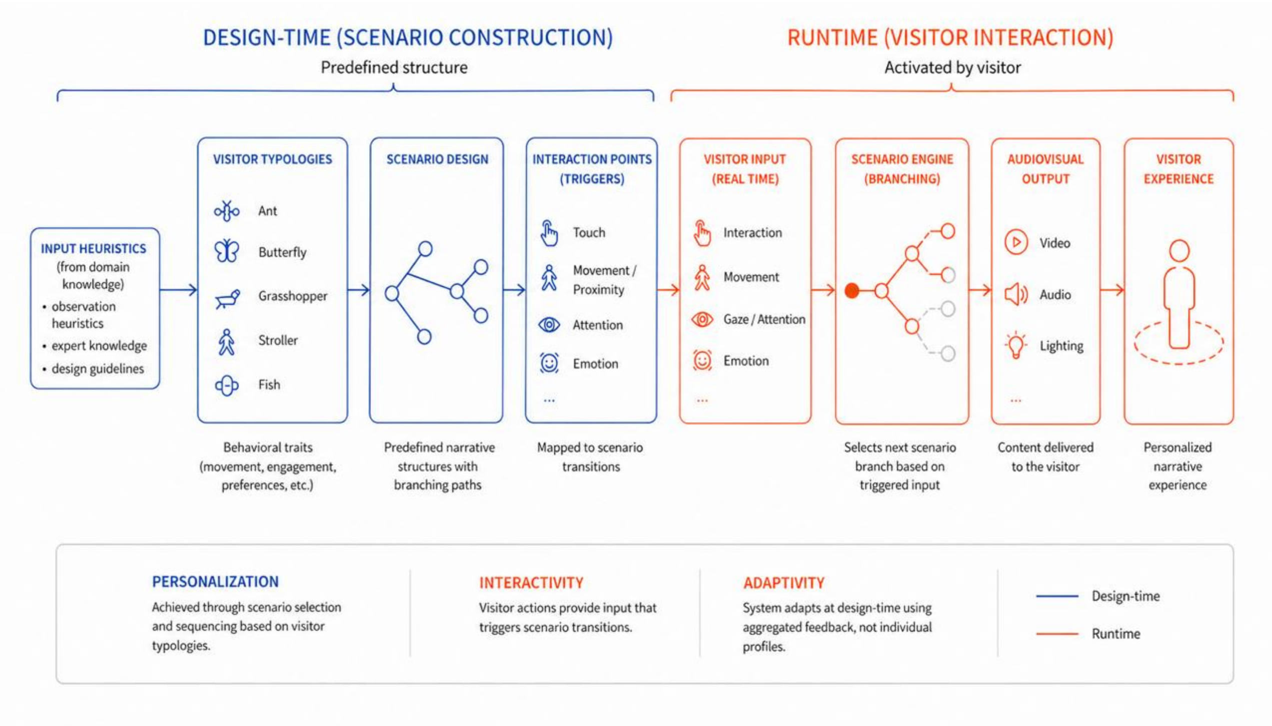

Figure 1. Approach summary diagram

support, rather than overwhelm, the exhibition structure.

In this sense, video can be understood as a universal and accessible narrative medium, capable of addressing diverse visitor behaviors without requiring individual adaptation. Through basic audiovisual techniques – such as rhythm, editing, and variation in framing – video content can respond to the main behavioral tendencies identified within the animal-based visitor typology. A faster pace and frequent changes in frame proximity help sustain engagement for "fish" and "grasshopper" visitors, who tend to move quickly through exhibition spaces. At the same time, this dynamic structure does not exclude "ant" visitors, who are generally inclined to spend more time with an exhibit and can engage with the content at their own pace. Furthermore, the forward-and-backward movement enabled by editing mirrors the non-linear exploration characteristic of "butterfly" visitors. In this way, video functions as a single, low-threshold narrative solution that remains accessible and meaningful across multiple visitor types.

While video mainly structures visual attention and temp, sound works through spatial perception, proximity and temporal continuity. Direct sound, surrounding sound and localized points can direct movement, enhance narrative transitions, and create moments of immersion without requiring eye contact. In personalized exhibitions scenarios sound is especially effective for supporting parallel narration layers, letting visitors stay physically involved in space, at the same time getting narration cues. Thus, video and sound have become one of the most developed mechanisms for directing and sustaining viewer attention.

Importantly, the production and presentation of video content no longer constitute a significant technical or financial barrier. Video recording has become widely accessible, and numerous examples of effective audiovisual storytelling can be found across digital platforms. As a result, video increasingly operates as a universal medium for transmitting messages, ideas, and narratives that is readily understandable to diverse audiences. Similarly, the methods of presenting video content within exhibition spaces are highly flexible, ranging from conventional screens and projections to more complex spatial installations. This versatility allows video to be adapted to different exhibition contexts, purposes, and curatorial intentions. Taking all this in account it seems that video can be the first solution for any museum, regardless of financial situation, to adapt the exhibition for a variety of visitors.

7 Implementing Scenario-Based Personalization in an Interactive Installation Écho d'Azur

The following case study shows how the scenario-based personalization logic developed in this article can be realized as a concrete interactive installation. The Écho d'Azur project was done using personalized narrative logic implemented through audiovisual media and machine learning techniques.

Artistic Vision and Intent

At the core of the project lies the wish to intertwine the rational and the emotional, the real and the illusory worlds created by human consciousness. The installation is created around the central theme of water, a symbol of change, adaptability, and reflection. As a symbol, water carries a duality that resonates through centuries: it can be creating or destructive, static or flowing. This perfectly connects with the nature of human emotions, as they are equally changeable,

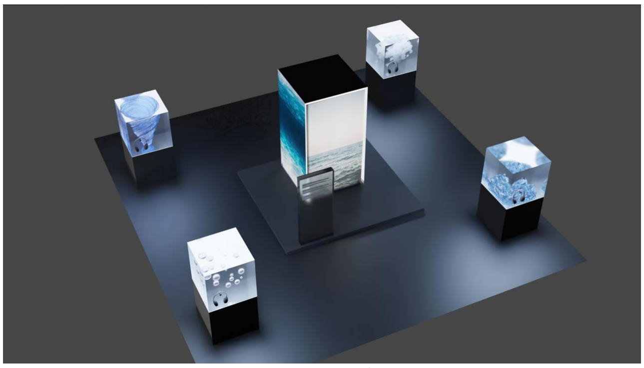

Figure 2. External appearance of Écho d'Azur Installation.

unstable, and multifaceted. From that point of view water is a mirror of the human inner world. Interaction with visitors occurs through a series of interactive elements that reflect and respond to these emotional states.

The general logic relies on Paul Ekman's classification of fundamental emotional states as a stable and widely used framework for mapping facial expressions to interpretable affective categories, as summarized by Tracy and Randles [2011]. Within the installation, this model functions as a computational abstraction that enables the translation of emotional cues (facial expressions) into predefined narrative responses.

Spatial Narrative and Immersive Experience

The main part of the installation is a large central cube that serves as a core interactive element. The cube is 2m high and 1m wide, and has a mirrored surface that initially reflects the viewer's image. Using facial detection and emotion analysis technology, the cube responds to the viewer's emotional state by transforming its surface into a dynamic water projection that visualizes the essence of their current emotions.

Surrounding the central cube are four smaller cubes, each representing a different state of water, from steam to ice, illustrating the versatility and unpredictability of water. These cubes are not just a visual object, a statue, but also a station with audio and headphones, they play sounds associated with the water state that they represent, strengthening the immersive experience. Altogether, this installation invites visitors to go into introspection and draw possible parallels between their inner world and the elements of nature – see Figure 2.

Spatial and Technical Specifications

The installation was designed for an area of 6 × 6 m, accommodating a central interactive cube, four peripheral cubes, and circulation space for visitors. This spatial configuration ensures the freedom of movement and stable conditions for interaction. Ambient lighting was kept dim in order to highlight the visuals, which constitute a core element of the installation's interaction design. The central interactive cube (100 × 100 × 200 cm) functioned as the main interaction node. One side of the cube was constructed from transparent acrylic and the remaining sides were opaque, in order to minimize external light interference and support immersive projection. This material configuration allowed the surface of the cube to shift between reflective and projected states, underlying the transition between observation (stand-by mode) and interaction (active phase).

Electrical and Projection Setup

The central cube had in it a compact computational unit, a projection system, and a camera-based sensing module to support the AI-driven interaction logic. The projector provided dynamic visual output on the surface, while the camera captured facial data for emotion recognition. All components operated locally to ensure low-latency response and stable interaction. The hardware configuration was designed to support continuous operation without disrupting the immersive experience.

Interactive Technology and Emotion Detection

The installation used an AI-based emotion recognition system, utilizing technologies such as OpenCV for image processing and TensorFlow for implementation of machine learning models. The system analyzed facial expressions captured through a USB-connected camera, processed locally using Python-based scripts. The video triggering mechanism was designed to respond dynamically to detected emotions. For each identified emotion, specific video loops (five videos, each lasting 1 minute) were projected onto the mirrored side of the cube, directly engaging with the viewer. Before the emotion is identified, the mirrored side displays a dark projection, to function as a reflective surface, all in order to enhance the viewer's introspection and immersion. Additionally, a longer 7-minute video was projected onto the three opaque sides of the cube to create an ambient atmosphere that complements the main experience. In this way, the audiovisual content presented to the visitor is not fixed in advance but is selected in real time and is based on detected emotional cues during the interaction with the visitor.

Within the frame of the project, the basic emotion model by Chizhik and Cokrlic [2024] was used to divide a person's emotional state into five main classes: fear, anger, sadness, joy, and a neutral state. Each of these states is further divided into subcategories for a more detailed emotional gradation. The data processing pipeline (Figure 3) in the installation starts with capturing a visitor's face using a USB camera. Then, the image is processed by OpenCV library, which identifies the presence of a face in the frame and prepares the data for the next stage of analysis. Afterwards, by using ThensorFlow, the MobileNetV2 model is launched, to analyze facial expressions based on a pretrained neural network.

Visitor typologies in the installation design

The design of the Écho d'Azur installation takes into account different visitor typologies described earlier in the article. The central interactive cube functions as a strong visual anchor: it attracts attention from a distance and supports visitors who prefer an overview mode of engagement, such as the "fish" type. These visitors can interact with the installation without approaching it closely and still receive a coherent experience.

The combination of audio points and smaller visual elements supports more dynamic and non-linear exploration.

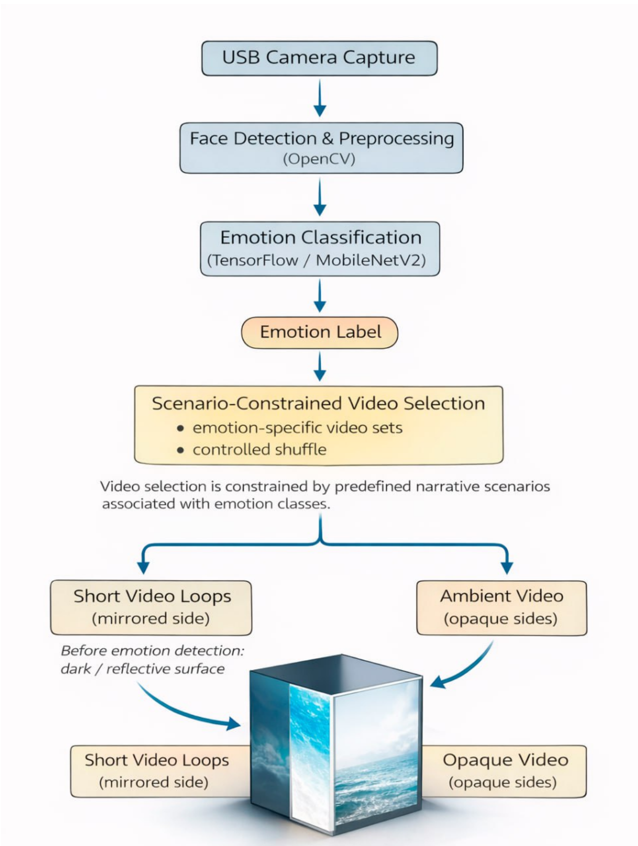

Figure 3. The data processing pipeline of the installation.

This is particularly relevant for “grasshopper” and “butterfly” visitors, who tend to move between separate elements and engage selectively. Short audiovisual loops and multiple interaction points allow them to enter and exit the experience at different moments.

At the same time, the installation provides sufficient depth for “ant” visitors. These visitors can spend more time at the central cube and engage with longer audiovisual sequences. The layered structure of content allows for repeated interaction and more detailed exploration. In this way, the installation does not adapt to individual users in real time, but offers a structured environment that supports different behavioral patterns through preconfigured content and interaction design.

Ethical Considerations and Data Handling

The Écho d’Azur installation includes real-time emotion recognition based on facial data. Therefore, ethical considerations related to data processing and visitor awareness were taken into account. The system operates locally and does not rely on external servers. All image data are processed in volatile memory during runtime. No images are stored, recorded, or transmitted.

The data lifecycle can be described as follows: A facial image is captured by the camera; The image is immediately processed for face detection and emotion classification; After classification, the image data are discarded and not retained in the system. The system does not perform identity recognition and does not create user profiles. Emotion classification is used only as a temporary trigger for selecting audiovisual content.

Visitors interact with the installation in a controlled exhibition context. The use of sensing technologies is limited to the immediate interaction moment and does not extend beyond it. This approach reduces risks associated with surveillance and long-term data collection while preserving the interactive functionality of the installation.

Advantages and Limitations of AI-Based Emotion Recognition

The MobileNetV2 model (that was implemented by Sandler *et al*. [2018] was chosen for the task of emotion classification, trained on the FER-2013 database (Facial Expression Recognition 2013) for its efficiency and ability to work with limited computational resources. The MobileNetV2 architecture has a number of key features that enhance its performance and efficiency. Inverted residuals, a key component, enable the use of lightweight deep convolutional layers by employing thin bottlenecks, significantly reducing computational and parametric costs. In these blocks, linear bottlenecks do not use activation functions at the end, which allows for more information to be retained from the input data and improves network performance with fewer computations. Like the ResNet architecture, MobileNetV2 includes skip connections, which improve the flow of information through the network and help mitigate the problem of gradient attenuation in deep networks.

Although MobileNetV2 provides efficient emotion classification, it has known limitations. Facial expressions may be ambiguous, and neutral or resting faces can be misclassified. This may lead to affective mismatch between the detected emotion and the visitor’s actual state.

However, within the proposed scenario-based framework, such misclassifications do not critically affect the system. Since the installation operates with a limited set of predefined narrative responses, the system selects from a constrained range of outputs rather than generating precise individual profiles. This allows the experience to remain coherent even in the presence of classification noise.

After determining the emotional state, the system uses a shuffle function to select one of the corresponding pre-prepared video clips, which is then projected onto the mirrored surface of the cube. Thus, the "Écho d’Azur" project is an example of computational methods combined with artistic expression. This project is a simple data processing pipeline that employs machine learning and neural networks for responding to individual emotional states of visitors in real time while also being a work of art. The success of "Écho d’Azur" underlines the possibilities of future installations to adopt similar technologies in order to deepen the visitor’s engagement and improve the communication between the audience and the art concepts.

At the same time different spatial and media components of this installation address the behavioural peculiarities of different types of visitors. Audio points combined with small-scale visual objects help to maintain sustained engagement by giving information via two channels (audio and sight), which is crucial for "grasshopper" and "butterfly" types of visitors (characterized by mobile and non-linear exploration patterns).

The central interactive screen functions as a shared visual point that accommodates multiple types of visitors. As an adaptive and visually dominant element, it attracts attention across the exhibition space and remains approachable from different distances. This is especially important for "fish" visitors, who tend to maintain spatial distance from exhibits and engage primarily at an overview level.

While having all the characteristics mentioned above, the installation also provides a needed depth for "ant" visitors, who are more likely to have prolonged and more profound engagement. The alternation between audio, video, and interactive elements supports better memorability through different information channels.

Taken together, Écho d'Azur demonstrates how a limited set of spatial and audiovisual components can be orchestrated to support diverse visitor behaviors within a single scenario-based installation. Rather than tailoring the experience to individual users, the installation operationalizes personalization at the level of behavioral typologies, confirming the applicability of the proposed framework in a concrete exhibition context.

8 Conclusion

This paper is a consolidated extended and revised version of three earlier studies by the authors that were introduced at the International Conference Internet and Modern Society (IMS 2025). The current research is based on a conceptual synthesis and design-oriented analysis of prior studies and proposes a scenario-based approach to personalization in interactive museum experiences, grounded in visitor typologies and narrative design rather than continuous real-time adaptation. A central finding of the study is the redefinition of interactivity as an operational instrument of personalization rather than an end in itself. Within the proposed framework, interactive elements function as narrative trigger points – moments of choice and feedback that activate predefined scenario branches. Interactivity generates input data, which personalization uses to select and sequence narrative elements. This structure aligns with the logic of recommendation systems, where algorithmic selection operates over predefined options rather than generating content dynamically.

The practical applicability of the proposed approach was demonstrated through the Écho d'Azur installation. The case study showed how scenario-based personalization can be implemented using a limited and interpretable data pipeline, audiovisual media, and machine-learning techniques without relying on extensive user profiling or continuous tracking. The installation operationalized personalization at the level of behavioral typologies, confirming that diverse visitor behaviors can be supported within a single experiential framework through careful orchestration of spatial, audiovisual, and interactive components.

At the same time, the study acknowledges several limitations. The proposed framework does not aim to replace fully adaptive systems, which may be appropriate in contexts where extensive sensing infrastructure, data governance, and technical resources are available. Instead, it offers an alternative strategy that prioritizes design-time logic over execution-time optimization. Future research may explore hybrid models that combine scenario-based personalization with selective adaptive elements, as well as empirical evaluation of visitor experience across different typology-driven scenarios.

In conclusion, the study argues that personalization should be understood not as an additive technological feature, but as a guiding logic for experience design. By repositioning interactivity as a narrative instrument and grounding personalization in typologized visitor behavior, the proposed framework offers a scalable, interpretable, and curatorially controllable approach to interactive museum experiences.

Declarations

Authors' Contributions

All authors contributed equally to the manuscript. Conceptualization, Methodology, Writing: Anna Chizhik, Katarina Cokrlic, Ekaterina Rybakova.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The source code created during the current study will be available in https://github.com/Frantsuzova after the exhibition period, expected to end by November 2026.

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