Sensing History: Contextualizing Artifacts with Sensory Interactions and Narrative Design

Jean Ho Chu[1], Daniel Harley[2], Jamie Kwan[2], Melanie McBride[3], Ali Mazalek[1,2]
Synaesthetic Media Lab & Responsive Ecologies Lab
Georgia Tech[1] Ryerson University[2] York University[3]
Atlanta, GA, USA Toronto, ON, Canada Toronto, ON, Canada
jchu35@gatech.edu, dharley@ryerson.ca, jamie.kwan@ryerson.ca,
mcbride.melanie@gmail.com, mazalek@ryerson.ca

ABSTRACT
We present three prototypes that aim to elicit historical and experiential qualities of 16th century prayer-nuts through narrative design and sensory interactions. Our goal is to enhance the presentation of cultural artifacts that must be presented behind glass to ensure their conservation. We aim to provide visitors with opportunities to form personalized connections with the past through historical, sensory, and embodied information that is otherwise unavailable. We use narrative design as a strategy to conceptualize and ground an experience that considers the contexts of users, their interactions, and the space in which the interactions occur. Together, our prototypes create an experience that is embodied, visual, aural, tactile, and olfactory. We present a brief review of related work, descriptions of the prototypes, our design rationale, and the results of our user study.

Author Keywords
Sensory interaction; narrative design; interactive museum; cultural artifacts; experience design; tangible and embodied interfaces.

ACM Classification Keywords
H.5.1. [Information Interfaces and Presentation]: Multimedia Information Systems – Animations; H.5.2 [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces – Haptic i/o, Input Devices and Strategies; Interaction styles, theory and methods; K.3.0 [Computers and Education]: General.

INTRODUCTION
Museums today present primarily visual displays of historical artifacts, with glass cases to ensure their conservation. Despite their original contexts of use, museum visitors have little or no access to the rich sensory and embodied information of these artifacts. Although museums and public installations have been creating experiential interactions that strive to engage the body and the senses, these exhibits are not widespread, and often ignore at least one of the senses. Within this field, there is an opportunity to enrich museum experiences with interactions that include the sensory aspects of the time, place, and use of an artifact. These experiences require design strategies that demonstrate an adherence to the original sensory qualities of the artifact.

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Figure 1. Visitor interacting with the prototype "Scents of Power"

As a case study, we present three interactive prototypes based on 16th century prayer-nuts. Our intersensory interactions use digitally-mediated objects, surfaces, and spaces, incorporating several of the original sensory aspects of the artifacts (Figure 1). We use narrative design as a means of structuring our interactions, providing visitors with opportunities to develop meaningful connections with the history and cultural practices of the prayer-nuts. Together, our interactions create an experience that is embodied, visual, aural, tactile, and olfactory.

The goal of our design is to help bridge the divide between the visitor and the artifact by encouraging a sensory, embodied understanding of the artifact's time, place and use. In our rationale and findings for the design of sensory interactions, we aim to show that sensory interactive experiences can recover some of the missing context to the history and use of cultural heritage artifacts. We suggest that such interactions may provide visitors with a meaningful, embodied, and personalized understanding of the artifacts.

While we did not have the opportunity to implement our prototypes in a museum, our lab setting afforded us the ability to focus our research on specific questions about historically-inspired interaction design. We suggest that interaction designers in museums can build on this work to allow visitors to experience sensory information of historical artifacts that is otherwise missing or inaccessible. In this paper, we discuss our narrative design, our methods for creating sensory interactions, and the results of our user tests. In our lab-based user tests, we examined how our participants responded to our sensory interactions, and how the experience might allow users to contextualize historical content. We begin with a brief review of related work.

RELATED WORK

The increasing variety of interactive experiences in museums and public installations suggests a growing interest in engaging the senses. Augmented reality exhibits [e.g. 14, 27] use smartphones and tablets to enhance the visual experience while giving visitors more control over how, when, and where they retrieve content. Exhibits that focus on sound can be triggered by physical presence and movement [e.g. 6, 32], or create evocative worlds, especially when designed for a particular site [e.g. 7, 8]. Although the conventional museum is still a 'hands-off' experience [26], touch exhibits are generally said to make museum experiences more accessible [20, 21], and more engaging for children [3, 21, 25]. Tangible interaction technologies have also given visitors a means to touch and handle exhibits [e.g. 1, 9, 12], through design that encourages tangible manipulation, exploration, or construction. Exhibits for taste [23] and smell [22] are much less common, and can require specific design considerations [11]. Given their marginalization, it can be especially important to include clear learning goals in exhibits that deal with taste or smell, as artist-researchers have done [24].

Although these examples can all be called sensory, one sense is often emphasized over the others at the expense of an experience that could engage multiple senses. It is worth noting, however, that the potential drawback of exhibits that do engage multiple senses can be an impression of novelty for its own sake. For example, recognizing the "overwhelmingly visual" gallery experience, the Tate recently created an exhibit that added taste, touch, smell and sound interactions to four paintings in its collection [31]. Unfortunately, this intervention appears to create experiences that are beyond the intentions of the artists, adding sensory information to work that never called for it.

On the whole, designers and curators are tasked with implementing clear and cogent interaction design that communicates how and why a user should interact with unfamiliar material [19]. Yet the very presence of technology is an interesting challenge. The relationship between, for example, a personal smartphone and an 18th century painting may not be readily apparent to visitors or to curators, and it is not necessarily clear how the addition of technology and interactions might contribute to a meaningful experience. Museum professionals sometimes refer to a 'curatorial narrative' [5, 21] as the secret to distilling and presenting historical concepts and practices to the museum-goer. Bedford [2, p. 60], for example, suggests that "finding and telling stories… [is a] critical strategy for museum programs and exhibitions." A cohesive narrative design may indeed be a means of addressing the challenges of creating sensory interactions for historical subject matter.

In the following section, we reflect on our prototypes as a case study for a narrative design perspective that aims to establish clear connections between how a user interacts, why, and with what content. We describe our use of the senses to communicate the otherwise inaccessible historical information of an artifact. With these methods, we hope to provide a meaningful context for the user's participation.

CASE STUDY: NARRATIVE DESIGN AND SENSORY INTERACTIONS

For this case study, we chose the 16th century prayer-nut as an example of an artifact that is delicate enough to require a glass case for preservation, while also originating from a complex sensory context. We use this artifact to test our narrative design and to show how sensory interactions can relate to historical information. We believe that the same process can be applied to other artifacts: all artifacts behind glass have and/or had certain sensory qualities that are not accessible to contemporary museum visitors. When choosing the prayer-nut, we asked, what are its sensory modalities? Are these modalities currently communicated to museum audiences? If so, how? If not, how can we encourage visitors to understand and experience these modalities?

To create the overall visitor experience, we conceptualized a narrative design strategy to invite visitors to use their sensory faculties in ways that relate to the original use of the artifact. This approach necessarily begins with a review of the historical subject matter to ascertain what interactions might contribute to a user's understanding of the artifact.

Figure 2. The interior (left) and the exterior (right) of a 16th century prayer-nut (Image courtesy of the Metropolitan Museum of Art)

Prayer-nuts

Created in the Northern European Low Countries in the 16th century, prayer-nuts (Figure 2) were intricately carved devotional objects that were symbols of wealth and piety [17, 28, 29]. Falkenburg [17] describes this as a time in which laypeople developed personal religious experiences, which included a "dependence of spirituality on material objects." [17, p. 32]. Carved from boxwood, the outer ornamentation

shows patterns and motifs similar to those found in Gothic architecture. When opened, each hemisphere reveals a detailed carving of a biblical scene surrounded by a ring of biblical text. Fragrant concoctions were likely inserted into the prayer-nuts; otherwise the prayer-nuts were used with pomanders, or with beads made of scented materials [17, 28, 29]. Measuring less than six centimeters in diameter, the prayer-nuts were a sensory encapsulation of the church in miniature.

Narrative Design

We cannot take for granted that users will know how or why they should engage in digitally-mediated sensory interactions. We use narrative design as a strategy to include a consideration for the users, their interactions, the space in which the interactions occur, and how each of these might relate to specific historical information. By narrative design we do not mean that we are creating stories. Rather, we are creating a set of interactions that allow users to situate the historical content within a personal experience, and possibly tell stories of their own. We frame our interaction design as incorporating three narrative qualities: character, action, and setting. We employ this narrative frame to provide clear, logical interactions that can be performed by the visitor.

Character: For our purposes, the character is the visitor. In our interactions, the visitor embodies the owner of a prayer-nut and becomes a subjective participant, or performer, acting from a first-person perspective. The visitor's interactions parallel the interactions of the original owner as a means of developing a personalized understanding of the artifact. The goal of this parallel is to provide a sociocultural context for engagement or interaction. We ask: who is interacting, why, and what is their relationship to the historical content?

Action: The actions are the historically-inspired interactions that evoke the original use of a prayer-nut, performed throughout our hypothetical exhibit. The set of actions is intended to be understood as a set of complementary experiences, with each action adding to the user's understanding of how the prayer-nut was used. Inspired by success in similar work [10, 15], we employ mimetic cues, which supplement the text and images that describe the required interactions. These cues show users how to interact by providing an external character in the form of images and animations who performs and situates the actions within a historical context. Overall, the actions aim to provide an entry-point into the history. We ask: what are the interactions, how will they relate to the actual practices involving this object, and how do these interactions relate to the visitor's understanding of the artifact?

Setting: The setting is a kind of ambient ecology, representative of meaningful sensory feedback, allowing visitors to construct a time and place through sensory experiences. In our prototypes, the interactions are layered to highlight one or more sense; together, we intend the prototypes to provide visitors with a rounded view of multiple sensory aspects of the artifact. As the 'setting' is comprised of three separate interaction stations, visitors are invited to choose where they begin their exploration of the content. Our goal with these separate entry-points is to account for differences in our visitors' aptitudes and predilections: each is based on a separate historical fact, and each is a valid way to enter into the historical narrative.

While it was not possible to implement at this stage, we conceptualized a possible layout for the interactions (Figure 3) wherein each prototype has its own interaction station. Our goal with these sketches was to reflect on how the environment might contribute to a holistic experience, inspired by the historical environment and constrained by the current environment. We ask: how do the character and the actions work together to contribute to the larger experience, and how does the entire environment contribute to an understanding of a time and place?

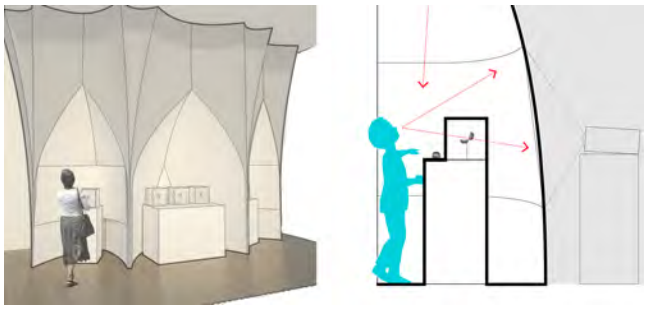

Figure 3. Concept sketch for a possible exhibition setting

Sensory Prototypes

We created three versions of the prayer-nut prototypes, each with its own interaction scenario related to a specific historical quality of the prayer-nuts. The prototypes are 3D-printed tangible objects embedded with sensors that are controlled by microcontroller boards. Each prototype has corresponding videos projecting in front or on top of the prototype, one of which includes audio effects. Rather than attempt to create exact replicas, the tangible objects borrow only the form and texture of the artifact to convey a tactile sense of scale and texture (Figure 4).

Later iterations will require more robust solutions with regard to both the technology and the tangibles: there is more sensory information that is either not communicated or

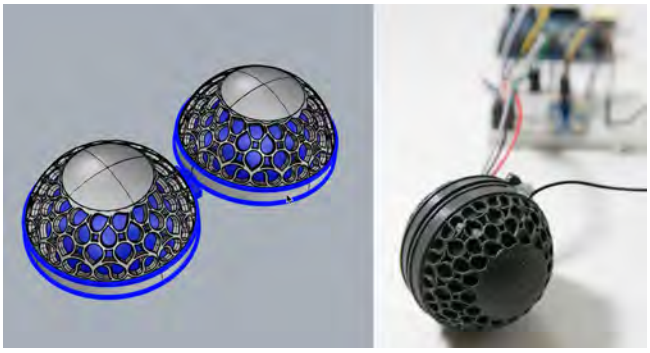

Figure 4. 3D model and the printed prayer nut

miscommunicated by 3D-printed (i.e. plastic) tangibles. 3D-printed objects allowed for rapid prototyping and testing, but we expect that a museum implementation could make use of boxwood or a similar high density wood, providing visitors with a true sense of the weight and texture of the originals.

"Visual Voyage"

Touching the outer carvings of the tangible object, the visitor explores the textures and details of the artifact. When the prayer-nut is open, it reveals a biblical scene ("The Crucifixion of Jesus") in its lower hemisphere, and an enlarged version of the scene is projected in front of the tangible object. Touching parts of the scene inside the tangible object highlights the corresponding sections in the projection, providing text that explains its narrative importance. In the current prototype, there are three such interactive points, created with momentary capacitive sensors that were made more precise with conductive paint.

"Visual Voyage" (Figure 5) provides a tactile interaction to engage with the prayer-nuts. Opening and closing the prayer-nut, or touching its outer and inner carvings, were integral for achieving a physical closeness to the sacred subject matter. Scholten [28, p. 19] writes, "Opening [the prayer-nut] allows the worshipper, as it were, to enter into the episode depicted. The manual act of opening and closing that this meditative technique entails is reminiscent of the opening of a prayer book, or even of the panels of a large altar."

In an effort to include an opportunity for embodied meaning-making, these actions, rather than just their visual outcomes, are important towards understanding how the prayer-nuts were actually used. Information that might otherwise be abstracted by text-bound media is conveyed through the act of holding the prototype and conscientiously touching specific points. Similarly, the enlarged projected image aims to provide visual information that would not be possible without magnification, or without actually handling the original artifact.

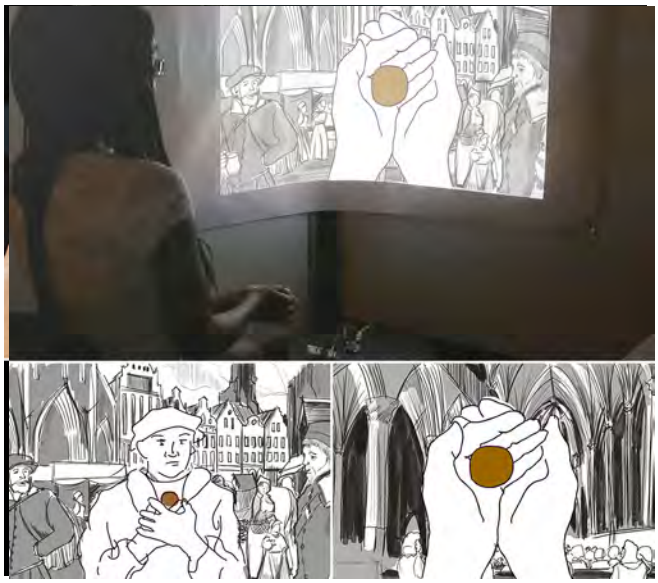

Figure 6. "Experiencing Spirituality" interaction (top) and projected animations (bottom)

"Experiencing Spirituality"

On approach, the visitor sees a projection of a historical layperson holding a prayer-nut and hears the sounds of a marketplace, complete with sounds of bleating livestock, birds, wind, and a multitude of voices. When the tangible object is held, a capacitive sensor triggers a transition in the projected image into the first-person perspective, showing hands holding the prayer-nut. Animations, text, and the sound of breathing suggest a breathing tempo. The scene of the marketplace transitions into a scene inside a church and the sounds of the market are replaced with sacred music written in the early 16th century.

"Experiencing Spirituality" (Figure 6) draws on the contemplative experience of prayer-nuts in 16th century religious practices. There has been a call for more 'techno-spiritual' interactions in HCI [4], but our design intention was an interaction that could have a broad appeal while still relating to the historical practices. We chose to focus this interaction on sound and breathing to create a relaxed or meditative experience. The prayer rituals were often private, personal experiences that took place outside the church, and this interaction reflects the owner's ability to use the prayer-nut as a kind of portable church. Falkenburg [17, p. 32] suggests that the prayer-nuts "aided and directed the soul during prayer and meditation," and represented a "complete meditative world encompassing in itself the entire rosary prayer" [p. 41].

The interaction itself only requires the picking up of the tangible object, but before and after this interaction the visitor is invited to listen to soundscapes for an unspecified amount of time. The soundscapes provide information about a time and place that is difficult to communicate through text alone. For example, the music was chosen to offer a clear contrast between the homophonic secular music of the time and some of the polyphonic sacred music of the Franco-Flemish school. In these works, rhythmic and instrumental differences are also apparent, and for greater historical accuracy, the recordings were chosen to feature musicians who use period instruments and practices, i.e. 'historically informed performance.'

"Scents of Power"

The visitor sees two tangible objects affixed to the table. Opening the objects activates flex sensors in the objects to trigger projected images onto the tabletop. The projection shows the fragrant ingredients of the prayer-nuts as well as text describing their historical importance. When both objects are opened, an animation appears that connects the objects with blending colors, implying the blending of smells. The visitor is invited to smell conceptual scents composed of essential oils, comparing the scents to those in their own lived experience.

"Scents of Power" (Figure 7) provides an interpretation of the scents used at the time, which would have served various purposes. Some carried metaphorical meaning, linking the owner of the prayer-nut with the church and the biblical texts; others were believed to have apotropaic qualities, warding off evil or sickness [13, 17].

As aroma historian Dugan [16] suggests, it is impossible to simulate exact "ephemeralities" or ambiances of the past. Therefore, our scent compositions follow a cultural and conceptual logic rather than a scientific one. The prayer-nut would have contained a variety of "sweet-smelling ingredients" such as herbs, oils, and dried flowers [17; cf. 30]. Our interpretation echoes the original with an emphasis on: nutmeg, cinnamon, clove, frankincense and a touch of rose. To simulate the missing aroma of the original prayer-nut's fragrant wood housing, we added sandalwood and cedarwood aromas. A second scent was created using ingredients more recognizable to contemporary audiences, with an emphasis on lavender and cinnamon.

With these compositions we invite visitors to identify, compare, and reflect on their lived associations of the aromas, engaging with historical information that would be inaccessible through words alone. Furthermore, the scents were designed to offer two levels of complexity. The more straightforward of the two, with essential oils of lavender and cinnamon, combines these relatively familiar scents to draw attention to this discernable link to the past. For the visitor, the scents and the act of smelling are an empirical source of information about the time, place and use of the prayer-nuts.

EVALUATION

We presented our prototypes in two lab-based user-tests. We iterated the design after the first, and expanded our analysis in the second. While our participants do not reflect the full gamut of museum audiences, we offer the results of these tests to raise the issue of missing sensory modalities in exhibit design, and to inform future work that seeks to create historically-inspired interactions.

Figure 7. "Scents of Power" interaction (top) and animations (bottom)

First Iteration User Test

We showcased the first iteration of our three prototypes to eight colleagues in our lab and conducted an informal user test consisting of observations and unstructured interviews to evaluate the usability of the prototypes. Our colleagues knew little about the project and had not seen the first iterations of the prototypes. Prior to interacting with the tangibles, we provided general information for each participant, briefly describing the history of the prayer-nuts, the purpose of the installation, and a key historical fact related to each prototype. The goal of our observations was to assess the use of the prototypes with regard to the following broad questions: (1) Interactions: Do the participants understand how to interact with the prototypes? (2) Experiences: Do the sensory interactions allow participants to form a personal connection to the content?

Interactions: Without any initial guidance, many of the participants did not immediately understand what interactions were available with the tangibles. Some showed hesitation in handling the tangibles, which are light and look somewhat fragile, especially as they are visibly wired to the Arduino. Similarly, when engaging with the interior of the object, participants were unsure of how many and what fingers they were meant to use to explore the tactile points. It was clear that textual, graphical and possibly tactile cues could easily have functioned as additional prompts to encourage the initial interactions.

Experiences: Several participants expressed that the use of sensory and embodied experiences resulted in a more personal encounter with the activity. "Scents of Power" was particularly successful in this regard, as many participants were eager to describe how the scents reminded them of people and places for a floral scent, and foods and cultural traditions for a spiced scent. "Experiencing Spirituality" was not successful at providing enough information about how to interact, and responses were mixed. Although some appreciated an open-ended interaction that included a focus on breathing and relaxation (and related it to their own prayer and meditative practices), most were also uncertain about how long they were expected to interact.

We realized that we had not provided sufficient instructions for how to interact, especially as there were three key factors that our participants were asked to negotiate: 1) unfamiliar subject matter; 2) unfamiliar interactions; and 3) an unfamiliar engagement with the senses. To create inclusive and accessible experiences, museum exhibits often supplement unfamiliar experiences with appropriate signage that details how and why the user is expected to interact. In preparation for a more formal user test, we clarified our text and images that introduce the sequence of required actions, and we refined the historical text for each interaction to explicitly state their significance and relation to the

interactions. We expanded the mimetic cues to show historical laypeople performing the required interactions for each prototype, rather than just one. Several technical imperfections were addressed and refined; although the visible wiring was more hidden, recreating the technology was not our main goal.

Second Iteration User Test

We ran a second user test in our lab with thirteen participants (eight male and five female), eleven of whom were graduate students. We conducted qualitative semi-structured pre- and post-task interviews to further understand how participants express their sensory experiences with the prototypes. The interactions were video recorded for further review and were transcribed and analyzed with discourse analysis [18]. Given the scope of this paper, we do not make any claim to the generalizability of our participants' utterances; instead, we use these findings to gauge a possible response to such interactions and to investigate how our narrative design approach might contribute to context, multiple entry-points, and personalized connections.

The three prototypes were set up on separate tables, and participants were invited to walk around and choose where to begin. In addition to our expanded interaction instructions, a researcher was on hand to act as a kind of docent to clarify interactions if necessary. The participants spent between one and three minutes per station, and came alone, in pairs, or in groups of three.

We used the opportunity of this second user test to focus on the responses to our narrative design and our sensory interactions. As we noted in our narrative design section, establishing a 'character' was an attempt to align the visitor with the original owner in order to support a personalized connection to the artifact; our 'actions' aimed to align the visitor's actions with those of the original use of the artifact; and our 'setting' included a consideration for multiple entry-points into the unfamiliar subject matter. With these factors in mind, we were particularly interested in how our participants negotiated and contextualized the subject matter with the interactions and with their senses.

'Character' - Personalized Connections

Our participants all expressed satisfaction with one or more of the interactions. The interactions led some participants to describe their experiences and the history in personal terms. The participants referred to various modern objects like toys, jewelry, cell phones, and make-up kits, drawing connections and parallels with their everyday lives.

"It is really a fun and an enchanting idea to me, to think of little worlds contained in small things, and I guess that was the appeal of toys that I grew up with, like Polly Pocket and Mighty Max, which is a boy version. I loved them a lot and played a lot" (Participant 8, male).

"Before I didn't know about the prayer-nuts, but now I know what it is, and I know how to use it, I can feel some similar feelings with them. So it was very informative and interesting" (Participant 1, female).

"I was really having this intimate moment with this object, which I think is what these objects tend to be about. They are personal" (Participant 9, male).

"It is more that, if I just saw the object, I would be, 'oh, this is a pretty item to use, in the 16th century.' Instead I am like, 'oh, people would take this on the street, and maybe look at it, smell it, and this is how it made them feel'" (Participant 11, female).

"As I was touching the object, I felt like I was becoming that person, because I was interacting with the objects, and I was also experiencing what those men were experiencing in the 16th century. So I felt I am experiencing that person's life as opposed to reading descriptions" (Participant 3, female).

These statements reflect ways in which handling the objects and engaging the senses can offer routes to personal connections to the past (e.g., 'toys that I grew up with') or present ('I was really having this intimate moment'). Statements made relation to a personal subjectivity (e.g., 'I was becoming that person… I am experiencing that person's life'), are interesting for the ways that participants bridge the gap between historical figures and themselves. However, these utterances may only signal their awareness of some of the intended ways of performing the interaction.

'Action' - Contextualizing Artifacts

After interacting, many participants described ways in which they were able to access information that would not have been available through text or visual displays. They described how sensory interactions contextualized the artifacts:

"By touching it, it tells you more about what the objects really meant for, which is what museum is really for. Because it is now there for you to know these thing exist. It is there for you to understand how, when, and why people used these things a long time ago" (Participant 7, female).

"You feel like you are actually experiencing the object, and thinking about the context. The evocative illustrations, and the use of sound, all these senses… it really puts it in context and it is not just an artifact divorced from context" (Participant 8, male).

"What is important is context. Like most of the time we go in a museum, and it is really boring because things are very, very removed from their original context, and the best that museums can do is put a little piece of writing next to it, that has to be really short, or no one is going to read it. And this is a good way of adding more context to the pieces" (Participant 11, female).

The participants did not all so explicitly state that the sensory interactions added context, but these examples suggest that some of our participants had already reflected on the paucity of such experiences in museums. The opportunity to use the

senses is stated in direct opposition to the conventional museum exhibit, which is "boring," with artifacts that are "very, very removed" or "divorced from context."

'Setting' - Multiple Entry-Points

As our interactions each aim to provide an alternate entry-point into the history, we found it important that most participants expressed interest in one interaction over the others. The varied preferences may suggest the value of designing additional means for visitors to engage with the subject matter, especially as the various personal experiences, interests, and abilities of the visitors require varying modes and levels of engagement. Conversely, this may also reflect the low ranking of certain sensory experiences within our dominant sensory order, which can inform our relative interest or disinterest in dominant and non-dominant modes of sensing.

"If you want to know more about this particular one and if you don't care about this other particular one, you can, like, go to what you are interested in, basically. In a multi-part experience you are able to choose what part of it you want to know more about" (Participant 8, male).

"I think [Experiencing Spirituality] was the most immersive for me. It had a very rich audio, not only a single track. I think you had music playing, you had street noise, you had some breathing, is that correct? I think that put me just in the context immediately, and then, plus the act of holding the prayer-nut, made me simulate the experience of actually using it. I was just enjoying the experience for a few minutes" (Participant 10, male).

"I liked the touching one [Visual Voyage]. So, when you see the painting, for example, and you see the description or listen to the audio guides, you have to look for some spots where the sentences are describing. But in here, each touching action itself focuses on things that in here it explains, so I liked that I didn't have to search for what kind of description this is referring to" (Participant 3, female).

"The smell itself, I think, just knowing it is like cinnamon and lavender, just reading it, it wouldn't have been very memorable. I would just like "oh, they have a smell" instead of like "oh this very particular smell I remember" (Participant 11, female)

These utterances convey an understanding of the differences in the types of experiences that each interaction offers, and how participants can follow their interests and choose where they begin. The varying experiences, whether related to the complex and layered media and the 'act of holding' in "Experiencing Spirituality," or the ability to focus on images and descriptive text with touch in "Visual Voyage," may also hint at the most important feature of these interactions. In providing these sensory interactions, we create an alternative to text alone (i.e., "just reading it"), with the senses providing meaningful information about the history of these artifacts that would not be available or accessible in a conventional museum exhibit.

DISCUSSION & LIMITATIONS

Our findings, especially in the second user test, are a promising first step for exhibit designers seeking to provide visitors with access to missing modalities and historical context. We acknowledge, however, that there are still many challenges in designing such interactions. The apparent novelty of certain sensory interactions, such as breathing or smelling 'on cue,' risks disengaging or confusing participants if the interaction is not clearly described. Our multiple-entry points could have had a more uniform design, or at least a design with clearer affordances: in their transition from a particular interaction from one prototype to another, participants were disappointed to find, for example, that one could not be opened, or another could not be lifted off the table. For some of our participants, design choices such as these detracted from the overall experience. This, perhaps, led some participants to suggest that some or all of the interactions could be consolidated into a single object. We had chosen not to, in order to focus the visitors' attention on individual historical facts. For example, our choice to have the scent applied to only one interaction is an opportunity to draw attention to why and how those scents were used and to focus the visitor's attention on a single aspect of the artifact. In our early brainstorming, we conceptualized a prototype that was a composite of all the interactions, but this soon came to seem cumbersome from the perspective of a visitor who is completely new to the subject matter.

It is likely that our 'actions' could have been improved by incorporating more embodied and material qualities for the objects. More accurate attention to detail in the look, feel, and weight of the objects would create a better sense of its tangible qualities. One participant did note that the plastic was comforting to handle because there was no serious risk of damaging the object, but it seems that wooden tangibles could have this same effect while being more historically accurate. The robustness of the materials and a consideration for their upkeep and maintenance over time would certainly be a concern if such replicas were implemented in a museum. In particular, we noticed challenges with the scent interaction that could be expanded in future work. In the first iteration of the user test, the scent was applied to the inside of wine glasses. In the second iteration, it was applied to wooden disks placed inside the prototype. A more sustainable application of the scents would require redesigning the replicas to easily house and replace the scents, while also making sure that the scents are never in contact with the visitors' skin.

We also observed that the structure of the interaction sequences, which could contribute to how our visitors, i.e. our 'characters,' personalized their experience requires further refining and testing. Some participants wanted clearer endings or stages throughout the interactions, others appreciated the open-ended quality of the interactions; one stated that not knowing "what is going to happen" (Participant 7, female) throughout the interactions sparked curiosity and a desire to explore what the objects could do.

Due to the constraints of our lab and budget, the full extent of our imagined 'setting,' in which the current environment informs the historical environment, was not feasible. This too would require further testing in a museum.

As we have noted, these are unfamiliar sensory experiences with unfamiliar objects. Much of the success of the second user test could be explained by the increased instructions and cues, and more scaffolding and carefully designed user prompts could encourage deeper engagement. For example, it was common for participants to only briefly inhale the scents; comparing, contrasting, and reflecting on the scents would likely have required repeated and/or deeper inhalations. There are many opportunities to include additional ways for visitors to not only learn about the objects, but also learn about their senses and sense practices. Sensory practices can themselves be scaffolded and encouraged, especially in order to develop literacies that can be applied outside the museum context.

CONCLUSION & FUTURE WORK

As interactive experiences become more common in museums, there is an opportunity to contextualize artifacts with historically-inspired sensory interactions. We believe that there is a significant opportunity for such interactions to recover some of the missing context of the history and use of cultural heritage artifacts in museum spaces. These interactions will require special considerations that account for visitors, especially with regard to how, why, and where they are asked to interact. To this end we offer our narrative design approach, a strategy that includes a consideration for how the visitor's interactions might contribute to an understanding of historical information. In our user tests, we examined how our participants responded to these unfamiliar interactions. While we do not claim that the results of our tests are generalizable, many of our participants reported that our sensory interactions added a degree of context, personalization, and embodied meaning-making.

While we see potential in this narrative design approach for other cultural heritage artifacts, practices and experiences, we also recognize that our use of character, action, and setting as the basic components of this design can be expanded. Our limitations are also opportunities for future work: the full extent of our 'setting' was not implemented, and could have provided embodied information that contributes to a sense of historical place; our 'character' was only loosely defined, and the visitor could have been given various choices to develop their own character, or perhaps could have followed a narrative arc; finally, the 'actions' could have been expanded to include gestures or movement. As the interactions become more complex, the questions that constitute our narrative design process can remain the same. We must continue to ask how we can provide the visitor with meaningful and contextual actions that create an experience that contributes to a better, more embodied and sensory understanding of history.

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