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Using Tangible Smart Replicas as Controls for an Interactive Museum Exhibition

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ABSTRACT

This paper presents the design, creation and use of tangible smart replicas in a large-scale museum exhibition. We describe the design rationale for the replicas, the process used in their creation, as well as the implementation and deployment of these replicas in a live museum exhibition. Deployment of the exhibition resulted in over 14000 visitors interacting with the system during the 6 months that the exhibition was open. Based on log data, interviews and observations, we examine the reaction to these smart replicas from the point of view of the museum curators and also of the museum's visitors and reflect on the fulfillment of our expectations.

Author Keywords

Tangible interaction; smart replicas; museums;

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI):
Miscellaneous;

INTRODUCTION

The design and deployment of interactive technology as part of museum exhibitions has long been a topic of study for HCI and related disciplines [e.g. 3,7,8,14]. Research on tangible, embedded and embodied interaction has meant a shift in approaching such design: from targeting separate devices that are interspersed within an exhibition (whether mobile visiting aids, or interactive desktop-PC stations [12, 14, 10]), to creating visitor experiences that are more fully integrated into an exhibition and that extend and complement its materiality and design identity [1, 6, 21].

A particular aspect of this latter trend of research is smart replicas, whereby replicas of objects that are either part of a collection or exhibit or related to it are built to embed

digital components to allow for their use as part of an interactive experience. The attempt to more fully integrate the use of technology with the materiality of a heritage display is part of a wider line of debate on making the museums and their artefacts more engaging for visitors, overcoming the separation between technology and heritage holdings. Many in the museum studies community also acknowledge the value of physical engagement and of emotion to foster a deeper appreciation (e.g. [9]).

In this paper we investigate the design and use of tangible smart replicas to interact with digital content within a museum exhibition. These smart replicas are used to access an additional layer of content that complements the traditional, factual information that is generally provided about objects in a museum. It uses personal narratives to tell stories related to the objects and places within the exhibition from different perspectives, thus shaping different visitor experiences and providing an emotional dimension to complement the factual one. These narratives are materialised via smart objects that are crafted reproductions of original objects that sit within the scope of the exhibition.

The design of the exhibition, titled “The Hague and the Atlantic Wall: War in the City of Peace”, was the result of a process of co-design, where interaction and product designers collaborated with museum staff to develop the interactional experience to be offered to visitors and to seamlessly integrate the smart replicas with the rest of the exhibition design. We examine the expectations of both the museum professionals and the interaction designers for such an exhibition and for the role of smart replicas, how these expectations shaped (and were shaped by) the co-design process and then reflect on these expectations in light of the visitor response to the exhibition itself and to the smart replicas in particular.

Specifically, we examine the use of smart replicas to control the presentation of digital content. These smart replicas offer a simple, walk-up-and-use interaction, requiring the visitor approach a display case and place the replica on it. We would expect such interaction should not require any real training, although an initial explanation may be required. By using replicas of actual museum objects the curators hope to make the visitors pay attention

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both to the replica and to the original object that it is a replica of. We also expected, based on the museum's experience of their visitors, that visitors would choose a single perspective (via a single replica) and then follow this perspective throughout the exhibition. We will discuss these expectations in light of our observations of visitors later.

In the following sections, we provide an overview of the use of tangible interaction and smart replicas in cultural heritage settings. This is followed by a description of the exhibition itself. We then present the collaborative process that led to designing and creating the smart replicas, as well as the implementation necessary to integrate them into the exhibition itself. Finally, we discuss the outcomes of this exhibition, including our own observations, from two perspectives: those of museum curators and of visitors.

TANGIBLE INTERACTION AND SMART REPLICAS IN CULTURAL HERITAGE

In the last few years, in parallel with the increasing interest in the physicality of the experience with museum objects shown by many works in museum studies [4, 9, 17], tangible interfaces have begun to be studied and employed in museums. Considering the term tangible interaction as an umbrella term encompassing "a broad range of different systems and interfaces relying on embodied interaction, tangible manipulation and physical representation (of data), embeddedness in real space and digitally augmenting physical spaces" [13], we see how tangible interfaces in their different forms have appeared in museums and cultural heritage sites. Indeed, in these places it is now common to find examples of tangible tabletops (e.g. [5]), interactive physical objects (see below), or embodied interaction [18]). In many cases, this has given rise to the creation of *smart objects*, physical objects people can interact with, and through doing so activate certain behaviors or reactions (e.g. activation of sounds or the delivery of video content). These smart objects are often derived from existing cultural heritage objects, either original physical objects [6] or copies of them that are augmented by digital technologies. In the case of such copies of original cultural heritage objects, we can refer to them as *smart replicas*. The work presented in this paper falls within this category.

The first experimentations in the design and implementation of smart objects and/or replicas (derived from cultural heritage objects) were carried out in the early 2000s. Many of these were feasibility studies or explorations of possible uses and were not integrated in the museums even when designed with a specific museum in mind (such as, for example, the low-fi prototypes described in [6 and 11]).

Recently smart replicas have begun to be employed in real-world heritage contexts. These often consist of 3D printed replicas of original objects used to trigger content in multimedia installations: one example is the work by Maaïke Roozenburg, examining how 3D prototyping can be

used to bridge heritage holdings with technology such as augmented reality, to increase the understanding of objects [19]. Another example is the VIRTEX system, used near an original object in order to enable visitors not only to hold the untouchable object as a replica and perceive all details of it but also to explore the meaning of the object through sounds and images [16; 2]. Similarly, at the Manchester Museum a nylon replica of the limestone Stela of Hesysunebef is endowed with touch sensors so that the visitors can touch the different symbols, objects or characters engraved in the stela and in so doing trigger images and sounds played on a nearby screen [20].

The project presented in this paper differs from many of the examples illustrated so far, as smart replicas are not used here as part of single interactive installations, but as objects that visitors can carry with them during their visit in order to activate contents in different parts of the exhibition. This has similarities with "Reminisce", where tangible tokens were given to visitors to carry around their exploration of an open-air museum in order to access different interactive experiences. In the case of "Reminisce" the tokens were not replica objects, but everyday artefacts connected with the themes and material qualities of the museum [8].

While the body of related work we have outlined has examined a number of important issues surrounding the creation and use of smart replicas, it has not yet explored in depth issues of designing and integrating this interaction modality in a long-term museum exhibition. In this paper we detail the collaborative envisioning of an interactive exhibition including a series of smart replicas. We also present our expectations of such an exhibition and of the smart replicas and compare them to our understanding of how these replicas were used by visitors to the exhibition.

'THE HAGUE AND THE ATLANTIC WALL'

The Atlantic Wall was a set of the defensive lines and placements that were built by the German forces during WWII along the coast of the Atlantic Ocean and North Sea, from Norway to the French/Spanish border. The wall consisted of a 5,000 km long chain of bunkers, anti-tank walls, cliffs and other barriers and was aimed at preventing an Allied attack on the Reich's Western frontiers. The presence of these fortifications affected several countries and cities, and their residents.

The "The Hague and the Atlantic Wall: War in the City of Peace" exhibition ran from April 9th to October 31st 2015 at Museon in the Dutch city of The Hague, a museum with a strong focus on hands-on exploration of exhibits. This exhibition focused specifically on the Atlantic Wall in The Hague. In this coastal city, the construction of the Atlantic Wall was rather different from the rest of the defensive line, and, because The Hague was the seat of the administration of the occupied Netherlands and the presence of a fishing port, it needed additional protection. The Allied forces could break through the coastal defence lines and reach The Hague from inland. To prevent this a second defence line

was created through the city. Thousands of buildings were demolished to make way for an anti-tank ditch and an anti-tank wall. Thousands of people had to leave their homes and be relocated to other parts of the country. Some parts of the city were no longer accessible to the inhabitants without special permits or were completely closed off to civilians.

The exhibition focused on the impact of the construction of the wall on the city and its inhabitants. Subjects like evacuation and daily life in an occupied city that had become a military fortress were important in the exhibition's storyline. The story was told by means of museum objects, documents, maps, models, photographs and videos, all displayed in an evocative environment inspired by the actual geography of the city. The exhibition space was arranged to correspond to a physical map of The Hague. Showcases were located at points that correspond to important locations within the city. Within these showcases were museum objects, documents, models and so on, together with traditional museum information labels and displays giving factual information about the contents of each case. This provided a more traditional museum visit experience. However, a separate layer of information, focusing more on personal stories, was also available in the exhibition. With this layer the museum hoped to allow visitors to explore the objects and locations in the exhibition from a number of different perspectives, based on the stories of people living in The Hague at the time of the construction of the Atlantic Wall. Through these stories, mainly based on interviews with eyewitnesses collected during a previous oral history project, visitors have a more evocative experience, not solely consisting of facts and figures, but of real experiences told by those who lived them. The use of interactive technology in the exhibition was focused on supporting this aspect of visit experience.

DESIGNING THE INTERACTIVE EXHIBITION

The design of the interactive components of the exhibition was a collaborative process, involving designers, museum curators and technicians. A number of co-design sessions took place over several months in order to create the final outcome. This process was initiated by the museum, as a result of a previous successful installation [15]. The co-design process was led by the technical and design partners, although final decisions on what would be included in the exhibition rested with the museum curators.

The initial proposal was to include a small number of standalone interactive showcases in to the larger exhibition, possibly displaying additional audio or video content related to only one or two objects in the exhibition. This was seen as an extension of the previous installation.

However, the design partners felt that there was an opportunity here to expand on what had been done

previously, and to create a more integrated experience for visitors. As a result of this the scope of the interactive portion of the exhibition grew over the course of the co-design sessions, until technology was embedded across the entire exhibition. In fact, the technology became a means of adding an additional content layer on top of the exhibition.

In order to realise this, the curators chose a selection of ten key museum objects from the Atlantic Wall exhibition to be augmented with digital content that could be triggered by visitors. Each of these objects has a story that can be told from multiple perspectives. For this exhibition, the curators chose three perspectives representative of those people that were living in The Hague at the time: Dutch civilians, Dutch civil servants, and the occupying German soldiers. The idea was to allow visitors to explore these objects, and thus the exhibition itself, from the perspective of different types of people: the story of a civil servant who was involved in running the evacuation will be different from the story told by a civilian who lost their home or the story of a German soldier enforcing the evacuation order.

The objects would be used as a starting point for a second, additional storyline throughout the exhibition. In this storyline different aspects of the Atlantic Wall in The Hague would be highlighted and told from the three different perspectives: What did it mean to lose your home had you been a civilian? How was it to carry out German evacuation orders for a Dutch civil servant? Why in the eyes of the German occupier was the Atlantic Wall indispensable for the population in the occupied territories? These related stories would be told on the basis of original sources such as interviews, documents from archives and periodic newspapers that had been transcribed and recorded in a studio with professional voice actors. The sound clips were combined with photographs and videos from different archives for displaying at various points in the exhibition.

A number of different methods were considered for allowing visitors to choose the perspective from which they would like to hear this additional content. The most obvious solution would have been to use buttons to activate the stories throughout the exhibition, i.e. one button for each of the three perspectives. However, rather than use this mechanism it was decided to create a more immersive experience, by offering smart replicas of real historical objects to trigger the stories.

These objects would be used to trigger the interactive content at each point within the exhibition. Each object would represent a specific perspective and language. Visitors would be asked to choose an object at the start of the exhibition, based on their preferred perspective and language.



Figure 1: The complete set of smart replicas.

This object would then be used to activate content, presenting the visitor with content and allowing them to explore the exhibition from a single overarching perspective. The hope here was that this process of choosing an object (and its related perspective) would make visitors more curious and result in a stronger involvement with the story being told than would be the case with the use of buttons throughout the exhibition.

CREATING THE SMART REPLICAS

As already discussed, the exhibition would contain content related to three perspectives: Dutch civilians, Dutch civil servants, and German soldiers. It was decided that content would be presented in two languages: Dutch and English. This created a requirement for six smart replicas, one for each perspective/language combination. Museon's curators chose six objects that they felt best represented the perspectives, as these were objects that would have been important to those specific groups of people: Table 1 lists the replicas and corresponding languages and perspectives.

Replica	Language	Perspective
Tea bag	Dutch	Civilian
Sugar packet	English	Civilian
Travel Pass	Dutch	Civil Servant
Armband	English	Civil Servant
Drinking mug	Dutch	German Soldier
Dictionary	English	German Soldier

Table 1: The list of replica objects and their corresponding perspective and language.

In order to use these objects as controllers, we needed to create replicas of them that could trigger the required content. These replicas were created using techniques including 3D printing, traditional papercraft, transfer



Figure 2: The set of original objects on which our replicas are based, on display in the exhibition.

printing and stamping, along with materials such as paper and cardboard. In this section we detail how these replicas were produced, along with some of the key issues in creating useable replicas for a museum installation. The full set of six replicas can be seen in Figure 1, while the original objects on display in the exhibition are shown in Figure 2.

As the smart replicas were to be openly available for collection within the exhibition, there was initially some concern that they would be taken away by visitors. Each replica is sized to be held comfortably in the hand, meaning that they are also small enough to potentially be placed in a pocket and forgotten. Given this, the issues of cost and ease of creation (also for replacements) were paramount for the museum when deciding on how to create the replicas.

However, it was also felt that the replicas should be of a high enough quality to not devalue them or the exhibition, and that they should offer similar qualities (particularly tactile and visual qualities) to the original objects. The goal was to create replicas that had enough perceived value, both monetarily and emotionally, to the visitor that they would respect them in use and return them at the end of their visit.

We decided to use materials that would be representative of the original objects to create the replicas. Thus, for those object originally made of paper or cardboard, these materials would be used for the replicas. For the mug however this would be problematic. In this case it was decided to create the mug using a 3D printer and a material designed to mimic the colour of the aged ceramic of the original mug and to print a partially transparent overlay that would add the effect of the painted scene.

Once suitable prototypes had been created, the next step was to optimise the process of producing them. The choice of materials, particularly paper and card, made for replicas that could be easily printed and assembled by the museum curators. To facilitate this we designed a kit for each replica: this included the physical materials and tools required to create the replica, the necessary digital files to print the skins of the replicas and video instructions on how



Figure 3: Toolkit for the sugar replica.

to create and assemble them. Figure 3 shows such a kit for the sugar packet replica. By creating these kits we enabled the museum staff to produce new replicas when they are needed, and to minimise costs by only producing the number they need. This process proved to be quite effective and the museum was very enthusiastic about it.

IMPLEMENTATION AND DEPLOYMENT

The implementation of the technology for the Atlantic Wall exhibition consisted of two main parts: the smart replicas (described in the previous section) and interactive display cases that are activated by these replicas. The replicas can be collected at the beginning of the exhibition: a display stand offers several of each replica to visitors. The display cases were designed to present audio and video content to the visitors. In total 10 interactive display cases were built into the exhibition.

Each interactive display case consisted of a standard museum display case that was augmented with a video project, an audio earpiece, and an NFC reader, all managed by an embedded Raspberry Pi. The “hotspots” for the NFC readers are indicated to the visitors by a pulsing orange light. When a visitor places their smart replica on top of this light, the light changes to a solid green and content is presented using the projector and the earpiece. This content is tailored to the specific language and perspective that is tied to the smart replica.

Each display case represents a physical location within The Hague that has some relationship to the Atlantic Wall. Inside each display case is an artefact that relates to that location. In order to emphasise the relationship between the artefact and the digital content being presented to the visitor, the content is projected on to the glass of the display case, from inside the case. This allows the visitors to look at both the object and the content, without requiring them to repeatedly switch focus between the two. Figure 4 shows one of these cases.

Content is streamed to each display case over a network built within the exhibition. This allowed us to store all of



Figure 4: A single interactive case within the exhibition.

the content on a central server. This makes it much simpler for the museum staff to update or replace content should there be any need to during the exhibition. All they need do is replace a video file and the next time a visitor plays this piece of content they will receive the latest version from the server. This central server is also used to anonymously log visitor interactions, allowing us to extract information regarding visitor numbers, their choices of language and perspective, and interaction with content.

RESULTS

The exhibition opened on the 9th of April 2015 and closed on the 31st of October 2015. In this period we recorded a total of 14853 sessions of visitor interaction with the exhibition using one of the smart replicas, with an average of 75 sessions per day. Of these, 11604 (~78%) have accessed the content in Dutch, with the remaining 3249 (22%) viewing the English language content. Overall, the most popular perspective was the civilian, followed by the German soldier, with the civil servant perspective being the least popular. Looking at each language separately, this ordering was also shown for the Dutch language sessions, but not for the English language sessions, where the civilian perspective was most popular. The number of sessions for each language and perspective is shown in Table 2.

Perspective	Dutch	English
Soldier	4768	936
Civilian	4484	1769
Civil Servant	2352	544

Table 2: Number of visitors for each perspective and language.

Visitors interact with the exhibition in a variety of ways. Some visitors view all of the content for their chosen perspective, while others view the content at only a small number of points within the exhibition (the mean number of content views per visitor is 4.85). Interactions are spread around the exhibition space. The mean number of interactions per case is 7203, although some cases are used more often (those nearest the entrance/replica collection

point), or much less often (in particular, one case is somewhat isolated from the others).

DISCUSSION: THE MUSEUM'S VIEW

The use of these smart replicas and digital content was quite a new experience for the museum and as such they had certain expectations (and worries) about its use. In the conceptual phase of the exhibition the museum curators considered the smart replicas as something additional to the exhibition: visitors could choose to use a replica or not. The exhibition was designed so that the replicas provided an additional layer of story on top of the factual information presented on the text labels in the exhibition. The curators' aim was that this content would be seen as a nice addition, something optional that visitors might or might not use.

Once the exhibition opened, the attitude of the museum to the replicas and their associated stories changed. Some museum staff and visitors expressed the feeling that without using the smart replicas they were missing an important part of the exhibition. Staff soon began to inform visitors that without the smart replicas they would experience only part of the exhibition: they are a core part of the exhibition, rather than the additional layer originally intended.

As we have described, each smart replica represents a specific perspective, and these perspectives correspond to people who lived in The Hague during the construction of the Atlantic Wall. To populate these perspectives the curators had to generate material for each perspective to be associated with each interactive display case within the exhibition. As these cases represent locations within The Hague the content should also refer to these locations. For some locations creating content for these multiple perspectives was straightforward, as source material was easily available. For other locations source material was only available for some perspectives. This required the curators to examine the available materials and attempt to find some that connect in some way to the required perspective and location. This resulted in an additional workload that had not been anticipated.

Yet this work was necessary in order to have a coherent experience of the different perspectives. This additional content requirement, and the resulting workload, was not something that the museum staff had experience of. When adding a layer of digital content on top of the exhibition they created a requirement for more content, and thus more source material. In the case of the Atlantic Wall exhibition each interactive case within the exhibition required 6 pieces of content, one for each perspective in each language. Adding an additional perspective or language would then cause a large increase in the amount of content needed. This is an issue to be aware of in the creation of these experiences. However, the museum staff did not object to this extra level of work. Rather, they were enthusiastic about the opportunity to present more material to visitors.

When it came to choosing smart replicas, the museum curators expected that visitors would choose based on the object itself, rather than the perspective. Initially it was not made clear to visitors what perspective each replica represented. Instead, displayed alongside each replica was a selection of quotations from the content, with the expectation that the visitors would choose a replica, explore the exhibition and discover the perspective through the content. However, it soon became clear that this confused and discouraged visitors. After a short period, the museum staff added labels near each replica explaining the perspectives and their relationship to the replicas.

The curators also expected that visitors would explore the entire exhibition using the smart replica at every interactive case. While most visitors do explore every case, our observations indicate that they do not always use the smart replicas at each of them. Some instead only activate the digital content at a small number of locations, where something has specifically interested them. This means that many visitors do not gather the overall story of a particular perspective as the museum staff had expected. However, it is interesting to note that the majority of visitors still take and carry a smart replica with them, even if they do not always use it, or do not use it at all. This is akin to how many visitors carry around a floor plan of a museum - an available visiting aid, ready if there is need for it.

DISCUSSION: VISITOR EXPERIENCE

In order to examine the experience of visitors to the Atlantic Wall exhibition, we have gathered data through a combination naturalistic observations and semi-structured interviews coupled with log data gathered from the technology itself. Our goal was to examine the use of replicas by visitors, including assessing what percentage of visitors used the replicas, and documenting recurring interaction patterns involving the replicas, whether individual (such as choosing replicas) or collaborative (sharing of replicas or discussions around replicas).

We performed five days of naturalistic observations, documented by both notes and video recordings of specific interactions happening at particular points of the exhibition; focusing on visitors (usually in small groups) going through the exhibition using the replicas. Two researchers documented visitor interactions and also held six semi-structured interviews with visitors, each lasting around 40 minutes. We also made use of log data, which contained details of each interaction with the technology by a visitor, including beginning and ending their visit and starting and stopping content playback.

From this data, we noticed that about 40% of people who visit the exhibition make use of the replicas to some extent, if no staff members are present to encourage them to do so. A much higher percentage of people use the replicas on days when staff are present. Furthermore, these patterns of use are also varied: from visitors who use the replicas at every available case to listen to all available content, to

people who carry a replica with them but only use it at certain hotspots. The latter type of visitors weaves the replicas use within their exploration of the exhibition easily, although they prefer not to avail of all available content.

The majority of visitors explore the exhibition using only one replica (e.g. one perspective). We have seen instances of certain people using one or two replicas early on in their visit so to understand how they work and which additional content they provide, the two cases nearest the beginning of the exhibition (where the replicas may be collected) are the ones used the most for this purpose. Some people then discard one replica and keep using the other, others carry on using both replicas for the rest of the exhibits, and others leave them both at the starting point and continue the visit without. These findings on the different degrees as to which people interact with the interactive components of the exhibition resonate with the literature on using public installations (see for example [2, 6]), where multiple levels of engagement are commonly observed, and where the possibility of freely establishing one's own preferred mode and amount of engagement is seen as a positive aspect of a public installation. Interestingly, however, pairs of visitors most often take two replicas: these are most commonly two different ones, but many also take two of the same object.

The choice of replica is down to two main factors: the qualities of the objects themselves, and the narrative perspective associated to an object. The latter seems to be the most common factor (in contrast to the original expectations of the curators); people have conversations around the replicas at the beginning of their visit discussing what the three perspectives represent and how interesting they will be. Choice of the object for its own qualities is the second most-common factor, with the exception of children who are more fascinated by the objects themselves, and spend more time handling them at the start point before they choose one. When asked the reason for their choice of replica in the post-visit interviews, participants (all adults) all referred to their interest in the particular perspective, and not in the object: for example, one elderly Dutch lady who was a child in The Hague during WWII and remembers living in the city when the Atlantic Wall was in place explained that she chose the perspective of the civilian as it represented her own experience of that period. Another participant, a younger Dutch man with a keen interest in the history of WWII, chose the perspective of the German occupying soldier as it offered him the opportunity to hear about historical facts from an unusual perspective. Another participant, a woman in her 50s visiting The Netherlands from the USA, chose the civilian perspective, as she felt that she could empathise with it the most. It seems clear from our data that for adult visitors the perspective is the most significant reason for choosing replicas.

In terms of the hands-on use of the replicas, adult visitors in small groups tend to use one or more replicas but not share them: the person (or persons) who picks up a smart object

at the beginning of the visit tends to be the one that uses it throughout: in the vast majority of cases we observed, replicas did not change hands. For family visits, replicas were often assigned to children, who remain in charge of the replica or replicas throughout the visit.

During the visit, the use of the replicas to activate additional content (by placing them on the hotspots) received mixed reactions: some visitors found it simple and straightforward, and used the replicas correctly from the very beginning of their visit; others, however, did not immediately grasp how the replicas were to be used, despite the presence of visible instructions in both Dutch and English and of labels on the hotspots themselves. For example, some visitors tried to use the hotspots as touchable buttons, before placing the replicas on them. Others placed the replicas on the projections on the case, rather than on the hotspot. It is worth noting that in the case of groups, when one person understands the mechanism of the replicas he/she usually shares this with the others.

The visitors who use the replicas tend to have positive things to say about them when asked in the post-visit interviews, although they also stated that they do not find them any easier to use than other modes of triggering content (and this resonates with the observational findings regarding some people's difficulties with using the replicas at the hotspots). People do like the fact that the object is a more characterful embodiment of a narrative perspective: they find the objects interesting and attractive to look at. However, few visitors realise that the smart objects are replicas: although the original museum artefacts are placed in a display case besides the replicas at the starting point of the exhibition (see Figure 2), almost no-one notices the originals. In our interviews, no participants had any comments to make on either the physical design of the objects, or on their connection to a perspective. With regards to the content activated by the replicas, a single visitor stated that she was expecting more factual information instead of "just stories". The others were satisfied with hearing personal stories.

Finally, a number of people visited the exhibition without using the replicas, particularly on days when no museum staff were present on the exhibition floor. For some of them this is not a choice in the sense that they do not notice the replicas at the start, but it is interesting to observe that some of the people who decide to visit the exhibition in a traditional way nonetheless show an attraction towards the objects at the start: they touch and explore them, sometimes examining all of them. The choice of not picking up the replicas could be due to the fact that they are not interested in exploring the additional layer of content, or it could be due to their difficulty in figuring out the role of the replicas in activating content in the exhibition, as already discussed.

CONCLUSION

In this paper we presented an interactive museum exhibition that made use of smart replicas to display content to

museum visitors. These replicas were used to create a layer of narrative content that was offered in addition to the more factual content traditionally presented in museums. Data gathered from the deployment of this exhibition showed that about 40% of visitors made use of the smart replicas without any prompting by museum staff, with a much higher uptake rate when staff actively promoted them. This indicates that such interfaces already offer an interesting means of controlling digital content in museums, and one that could become very popular with visitors as such technologies become more common.

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REFERENCES

1. Steve Benford, Andy Crabtree, Martin Flintham, Chris Greenhalgh, Boriana Koleva, Matt Adams, Nick Tandavanitj, Ju Row Farr, Gabriella Giannachi, and Irma Lindt. 2011. Creating the spectacle: Designing interactional trajectories through spectator interfaces. *ACM Transactions on Computer-Human Interaction*, 18(3), Art 11, 1-28.
2. Harry Brignull and Yvonne Rogers. 2003. Enticing People to Interact with Large Public Displays in Public Spaces. In *Proceedings of the IFIP TC.13 International Conference on Human-Computer Interaction (INTERACT 2003)*, 17-24.
3. Carlotta Capurro. 2014. Tangible interfaces in digital museum applications. http://bmuseums.net/wp-content/uploads/2014/11/141029-tangible_interfaces.pdf
4. Helen J. Chatterje. 2008. Touch in museums: policy and practice in object handling. Oxford: Berg.
5. Jean Ho Chu, Paul Clifton, Daniel Harley, Jordanne Pavao, and Ali Mazalek. 2015. Mapping Place: Supporting Cultural Learning through a Lukasa-inspired Tangible Tabletop Museum Exhibit. In *Proceedings of the ACM Conference on Tangible, Embedded and Embodied Interaction (TEI '15)*. ACM, New York, NY, USA, 261-268.
6. Luigina Ciolfi. 2007. Supporting Affective Experiences of Place Through Interaction Design. *Co-Design*, Volume 3, Issue S1, 183 – 198.
7. Luigina Ciolfi and Liam Bannon. 2002. Designing interactive museum exhibits: enhancing visitor curiosity through augmented artifacts. In *Proceedings of the European Conference on Cognitive Ergonomics (ECCE11)*, Catania (Italy).
8. Luigina Ciolfi and Marc McLoughlin. 2011. Physical Keys to Digital Memories: Reflecting on the role of tangible artefacts in “Reminisce”. In *Museums and the Web 2011: Proceedings*, J. Trant and D. Bearman (eds). Museums and Archives Informatics, Toronto, 197-208.
9. Sandra Dudley. 2010. Museum materialities: objects, engagements, interpretations. Routledge, London.
10. Rebecca E. Grinter, Paul M. Aoki, Amy Hurst, Margaret H. Szymanski, James D. Thornton, and Allison Woodruff. 2002. Revisiting the Visit: Understanding How Technology Can Shape the Museum Visit. In *Proceedings of the ACM Conference on Computer Supported Cooperative Work (CSCW 2002)*, 146-155.
11. Tony Hall, Luigina Ciolfi, Liam Bannon, Mike Fraser, Steve Benford, J. Bowers, Chris Greenhalgh, Sten-Olof Hellström, Shahram Izadi, Holger Schnädelbach, and Martin Flintham. 2001. The visitor as virtual archaeologist: explorations in mixed reality technology to enhance educational and social interaction in the museum. In *Proceedings of the 2001 conference on Virtual reality, archeology, and cultural heritage (VAST '01)*.
12. Christian Heath, Dirk vom Lehn, and Jonathan Osborne. 2005. Interaction and Interactives: collaboration and participation with computer-based exhibits. *Public Understanding of Science* 14(1), 91-101.
13. Eva Hornecker and Jacob Buur. 2006. Getting a grip on tangible interaction: a framework on physical space and social interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06)*, 437-446.
14. Eva Hornecker and Matthias Stifter. 2006. Learning from interactive museum installations about interaction design for public settings. In *Proceedings of the 18th Australia conference on Computer-Human Interaction: Design: Activities, Artefacts and Environments (OZCHI '06)*, Jesper Kjeldskov and Jeni Paay (Eds.), 135-142.
15. Mark T. Marshall, Nick Dulake, Daniela Petrelli and Hub Kockelkorn. 2015. From The Deposit To The Exhibit Floor: An Exploration On Giving Museum Objects Personality And Social Life. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15)*, ACM, 1917-1922.
16. Daniel Pletincks. 2007. Virtex: a multisensory approach for exhibiting objects. EPOCH KnowHow Books.
17. Elizabeth Pye. 2008. The power of touch, handling objects in museum and heritage context. Left Coast Press.
18. Jessica Roberts. 2015. Exploring Effects of Full-body Control in Perspective-based Learning in an Interactive Museum Data Display. In *Proceedings of the ACM*

Conference on Tangible, Embedded and Embodied Interaction (TEI '15), 445-448.

19. M. Roozenburg. 2013. Smart replicas: bringing heritage back to life. In *Smart Replicas*, The Hague: Royal Academy of Art, 28-31.
20. Samantha Sportun. 2014. The Future Landscape of 3D in Museums. In Nina Levent and Alvaro Pascual-Leone (eds.) *The Multisensory Museum. Crossing-Disciplinary Perspective on Touch, Sound, Smell, Memory and Space*. Rowman & Littlefield.
21. Robyn Taylor, John Bowers, Bettina Nissen, Gavin Wood, Peter Wright, Qasim Chaudhry, Lindsey Bruce, Sarah Glynn, Helen Mallinson and Roy Bearpark. 2015. Making Magic: Designing for Open Interactions in Museum Settings. In *Proceedings of the 2015 ACM SIGCHI Conference on Creativity and Cognition (C&C '15)*, 313-322.