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The Loupe: Tangible Augmented Reality for Learning to Look at Ancient Greek Art

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ABSTRACT

With the advent of digital museum interactives as a widely available learning offer in all types of museums, including history of art and archaeology museums, an ongoing debate has been established: Do these - usually screen-based - museum interactives assist visitors in focusing and apprehending museum objects and artefacts? Or do they distract and take away the attention from the real museum objects on display? We present the Loupe, an Augmented Reality tangible in form of a magnifying lens, proposing relevant interaction metaphors allowing museum visitors to get information in context about museum artefacts. We detail the design and content creation process that was employed in order to create a thematic tour for the the Greek Gallery of Allard Pierson Museum in Amsterdam. A medium-scale audience research study was carried out, using both qualitative and quantitative evaluation methodologies in order to explore the utility, usability and ease of use of the Loupe as well its learning and affective impact on the study participants. Our findings suggest that the acceptance of the Loupe, both as a museum interactive and learning resource, was related both with its qualities as an AR-enabled tangible as well as with its content and the devised form and structure of the overarching narrative revealed.

KEYWORDS: Augmented Reality, Tangible Interaction, User Experience, Museum Visit, Evaluation, Emotions, Learning

1. INTRODUCTION

Museums and Cultural Heritage institutions worldwide seem to increasingly recognize that catering for the preservation, study and documentation of museum artefacts is at least as important as engaging with their visitors for purposes of education, study and enjoyment (ICOM, 2007). As a consequence, a large variety of different interpretation, communication and education strategies are being employed in order to facilitate discovery and learning and engage the visitors with their museum visit. Within this context, digital interpretation strategies for on-site gallery visiting have recently become more common and widespread. There are many different types of on-site digital interpretation resources, ranging from museum interactive installations, information kiosks, audio guides, audio or multimedia guides or mobile-apps. One of the common characteristics these digital media often share is that they are screen-based. An ongoing debate has been established about whether these learning offers assist the visitor s in getting more out of their visit or whether they steal the attention from the real objects on display to the device, installation, or interpretation resource instead, to the detriment of the real object on display, favouring a "heads-down" attitude while visiting a museum (Hsi, 2003).

Recently, Augmented Reality (AR) based applications have started to be introduced in museums. AR applications have the advantage of making the real the point of reference while "augmenting it" or supplementing it with visual overlays, providing access to different layers of information a visitor can interact with. Despite the large variety of AR displays (AR installations, mobile, handheld multimedia guides, AR glasses, lightweight and see-through displays) and applications, it seems that the question of focusing on the virtual while distracting from the real remains an open challenge (Grinter et al., 2002; Damala, 2009; Damala, 2014).

We present the Loupe, an AR tangible that has the form of a magnifying glass. Within a wooden case having the form of a Loupe, an iPhone is enclosed. The Loupe offers a limited and well-defined set of interactions that allows a visitor to explore museum artefacts. For this study, a thematic tour was implemented in Allard Pierson Museum (APM) using a scavenger game (or treasure-hunt game) approach. The visitor holds the Loupe upright, receives a first hint on the concealed iPhone screen and identifies the exhibit for which content is available. Once the correct object is matched with the outline displayed on the Loupe's surface, the content flow starts and the thematic tour narrative starts to be revealed: the visitor tilts right or left to move forward or backwards in the narratives revealed, then searchers for the next object included in the thematic tour (Figure 1a-1c). Embedding iPhones, tablets or other interactive screen devices is one of the established strategies in developing and prototyping tangible interfaces (O'Malley, 2004).

This paper presents the main findings of a visitor and user experience study which was conducted with 22 adult participants. Section 2 provides the rational and motivations underlying the design of the Loupe as an AR tangible for museum visiting. Section 3 elaborates on the design of the Loupe, the underlying requirements and the guidelines that drove the content creation process. Section 4 describes the evaluation protocol and methodology adopted as well as our main research questions. Section 5 details the most important findings in terms of utility, usability and enjoyability of the Loupe both as an interactive, tangible device and application and as a learning offer and educational resource for museum visiting. Section 6 resumes our main conclusions while section 7 presents open challenges and directions for future work.

2. DESIGN FOR TANGIBLE AND EMBODIED INTERACTION

Frequently, museums attempt to provide access to background information on exhibits via information terminals and touch-sensitive displays positioned nearby. With these digital technologies, more content can be made accessible than was possible with traditional displays (on wall boards and labels), without dominating the room. But it is not clear whether visitors do want to read large amounts of text in the museum (Hornecker and Stifter 2006; Adams et al. 2004).

Researchers and curators express concern about technology distracting from the exhibited artefacts (Bannon et al. 2005; Macleoad 2013; Martin 2000; Pujol-Tost 2011; Schwarzer 2001; vom Lehn and Heath 2003). Screen-based technologies in particular (this concerns mobile devices and large screens alike) tend to be 'attention-grabbers' that risk to distract from the original artefacts (Martin 2000; Pujol-Tost 2011; Schwarzer 2001; vom Lehn and Heath 2003). Interactive installations are only considered successful if they increase visitors' attention to the objects on display, their understanding and appreciation thereof (Adams et al. 2004; Economou 2010).

This raises the question whether our device, the Loupe, would distract visitors from the exhibits it provides information about. While visitors have to hold the Loupe up to the object, they then see content on the screen. However, changing the form factor by embedding the screen in a tangible object such

as the Loupe may alter the way a device is used and experienced. Different shapes offer different affordances (Gibson, 1977), and having a handle to hold it with, could, for example, make it easier to hold the device or indicate which way to hold it even if the screen is off. The form factor of the magnifying glass invokes a metaphor and cultural form (Horn, 2013) that can evoke how to use the device, but also implies that several people may look through it and that it can be handed over (unlike a phone, it is not a personal device). Moreover, within the Loupe casing, the device is not experienced as a phone, but appears as a dedicated device with a specific functionality.

3. THE LOUPE

3.1. Conceptual development of the Loupe

The Loupe is one of several exploratory prototypes created in the first year of the meSch project, seeking to explore the potential of co-designing novel platforms for the creation of tangible exhibits at heritage sites (Petrelli et al., 2014). The initial design question formulated by the APM was to develop a tool that would allow access to multiple layers of information, with multiple perspectives being accessible using the same device. The central assumptions in the conceptual development of the Loupe were that: a. the Loupe would provoke a more active attitude from the visitor than a standard iPhone or iPad would do; b. that a visitor would look better, longer or more intensely at the objects, as the object remains central in the camera view; c. that visual (layers of) information create a new interesting way of storytelling in the museum, moving away from the more factual text style of most museum information signage.

The Loupe was imagined after a workshop session at the APM in which a number of early interaction ideas were tested with cultural heritage professionals. To be able to evaluate the ideas, paper prototypes were developed by Waag Society. One of those ideas was a monocular that would allow a visitor to zoom in on objects and see things that would not be able to be seen otherwise. Making 'the invisible visible' (Damala & Stojanovic, 2012), which is also one of the main promises of AR applications, was something that was evaluated as a promising route, but the monocular idea was discarded as a too individual activity, isolating someone from the visiting companions and the social context of the visit. From this feedback the idea of a Loupe was distilled as it would be possible to look through it with more than one person, especially if the functionality would include 'capturing' information so it would remain on the display until actively discarded (so the user would be able to show it to someone else as well). The metaphor of a Loupe, in essence a research tool, also connected better to the academic orientation of the institute. In terms of content, the Loupe was originally imagined to show visual information, such as the inside of an object, the contents of an object, or the original context in which the object was placed or discovered, while the Loupe metaphor was thought to intuitively instil to the visitors a "look through", "observe" rather than a "listen to" attitude.

3.2. Technical development of the Loupe

The Loupe basically consists of a wooden casing in the shape of a Loupe (or magnifying glass) that holds an iPhone 4s inside. The Loupe prompts its user to search for an object by displaying its outline on the concealed iPhone display. On the iPhone runs an AR application that is developed using the Vuforia AR Software Development Kit (SDK) for mobile devices that enables the creation of AR applications. The AR functionality enables the app on the iPhone to use the camera and to connect the physical realm with digital content and overlays. As the visitor looks through the phone's display (using the iPhone's camera view), the AR functionality prompts him to actively search for a target, in this case, an object inside the museum, based on a pre-programmed outline of that object, i.e. a transparent PNG. If the visitor matches the target –in this case the outline of the object in the see-through mode with the right physical object- the pre-connected media content is displayed. The visitor can tilt the Loupe to the left or right to move on (to the next outline or the next 'page' of content), using the embedded sensors of the iPhone that detect motion.

The first iterations of AR on Loupe were based on the Vuforia SDK examples, from which the interaction has been expanded. There are three groups of variables for designing an AR Loupe 'exhibit': i. TARGET, the element that is the subject of "inspection" or augmentation, for example a specific artefact in the museum; ii. ACTION, an interaction mechanic with the Loupe; iii. CONTENT or what is presented in the augmentation layer, this can be an image, text, video or 3D model. The use of the existing functionality of the iPhone was programmed in an IOS development environment. The casing of the Loupe has been made using the ShopBot, a 3-axis milling machine, in the Fablab Amsterdam (http://fablab.waag.org/). As is customary with Fablab activities, an instructable (a user-created and uploaded "blueprint" providing step-by-step instructions for a Do-It-Yourself project) will be published on the Fablab website to be able to share the design. Main challenges in setting up the interaction

with the object are calibrating the Loupe at the exact location (taking in condition the lighting conditions that might vary and the different angles from which the visitor will approach the object) and creating appropriate visual and textual content. This process is described in the following section.

3.3. *Loupe Narrative and Content Creation*

An additional key requirement of the study was to cater for fast and easy in-house creation and update of the Loupe content. As a consequence it was decided to primarily work with content types that curatorial staff were familiar with (van der Vaart & Damala, 2015). We thus focused on text, supported by a small number of images, some of which GIFs, and one sound clip instead of favouring rich 3D visuals. Furthermore, a series of suitable objects had to be identified within the museum galleries for this pilot study: as object recognition software requires a stable image of the object that is to be recognised, it was essential that the chosen display case was free of reflections and changing light conditions, and had a solid backboard, rather than having glass on all sides to enable an easy and robust identification. Most importantly, earlier smaller studies with the Loupe had shown that visitors struggled to identify individual objects that had AR content associated with them, when the AR experience did not provide an overarching narrative linking the objects together and taking visitors, as it were, from one object to the next. In addition, it had become clear that visitors found it challenging to find the next object in the AR tour, when this object was located in a different display case than the object they had previously engaged with.

Therefore, it was decided to create an AR tour, using a clear narrative and guiding visitors from one object to the next, where all object were situated in the same display case. The permanent exhibition of the Greek gallery was chosen as the location of the study. Taking all these requirements into account, the curator of the Greek collections, suggested using a display case labelled 'Gods and Heroes' containing artefacts depicting various Greek gods, heroes and other lead characters from Greek mythology. The main narrative evolved around the various affairs king of the gods Zeus had with goddesses and mortal women alike and the illegitimate children that were the result of these affairs. Recurring themes were the many disguises Zeus used to trick the women he intended to court, as well as the revenge of his wife Hera aimed at said women and children, whenever she discovered her husband's betrayal.

Since the size of the Loupe's screen was limited and the museum's curator had previously written narrative text for social media platform Twitter, the first draft of the text was written as if it were a series of tweets. The curator also supplied one short piece of lyre music, an ancient Greek harp-like instrument, to accompany an image depicting this instrument and supplied various images that could be used to illustrate the stories that were being told. Two sets of these images were turned into a simple GIF image by Waag Society which also reviewed the written texts and advised on narrative techniques suitable specifically for the Loupe's interaction affordances that were created in-house. After identifying the 'micro-narratives' that were to be included in the Loupe, the short pieces of text were rewritten to match a series of best practices for on-gallery museum texts in general (Van der Vaart & Damala, 2015).

It was hoped that best practices that were identified for general on-gallery museum texts, would be equally valuable when developing content for this digital AR tool. Two of these were in fact facilitated by the physical affordances of the Loupe itself, in particular the small screen of the device. Firstly, it required the texts to use short sentences and simple sentence structures and secondly, it demanded the text to be divided in short chunks, small enough to fit in the screen. This meant a visitor would leaf through several 'pages' of short text with each object that was included in the tour (Bitgood & Patterson, 1993; Bitgood, 1993; Ekarv, 1999). In order to hold visitors' attention, which is selective and limited, but also has focusing power (Bitgood, 1993), the text was made more salient (Bitgood, 1993) by using so called 'cliff hangers' in the short segments of texts, encouraging visitors to read on. Finally, to help visitors balance their attention between reading text and looking at the objects, the texts at times directly referred to the objects, asked questions about their physical appearance and highlighted elements that were of visual interest (Bitgood, 1993).

Initially, it was decided to focus on the main narrative first and foremost for each new object, highlighting the links between the figure depicted on the object and the main storyline of Zeus' infidelity. However, in the final editing round, after consultation with the concept developer, it was decided to use these first sentences to answer the question 'What are we looking at?' focusing on the object and what is depicted on it. In the following sections, links to the narrative would be made clear. This approach matches research carried out by Bitgood, in which it became apparent that visitors are more likely to read texts that are directly linked to a physical object (Bitgood, 1993).

The thematic tour to be taken using the Loupe finally included 6 objects (among the 18 objects of the showcase) and more specifically 4 ceramics and 2

statuettes. The final text consisted of an average of 7 "pages" of content per object, consisting mainly of short text phrases, but in the case of 5 objects also including one other content form, such as image, GIF or sound file.

On-site and in front of the showcase, a stand was installed from which the visitors would pick-up the Loupe. Upon the surface of the stand short text instructions were available on how to use it. Once the Loupe was held upright for the first time, a short tutorial would appear on the screen (Figure 1c) instructing the visitor to identify each augmented object using the object's outline. Upon a successful match, the outline would grow, pulse and fade out and the first "page" of available content would appear on the Loupe's display. Tilting the Loupe to the right made the next content "page" appear, tilting left the previous one. Once each micro-narrative was over, a new outline would appear and the new object had to be identified by the visitor.

4. EVALUATION METHODOLOGY

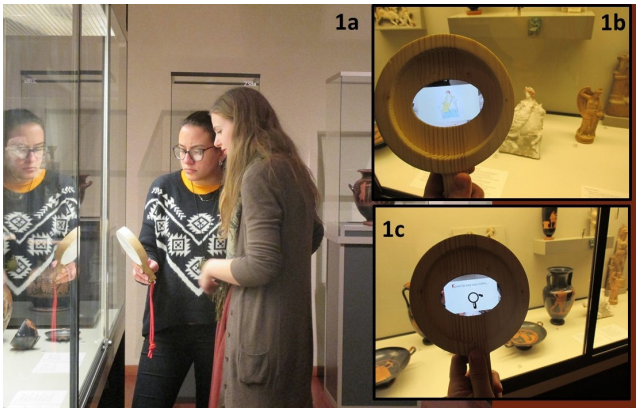
The design principles and motivations presented in the two previous sections assisted in formulating the main research questions to be explored during the field study. The main issues we tried to tackle were the following: Do visitors become more active and inquisitive when using the Loupe? Is the Loupe easy and intuitive to use and how much guidance do people need? Is the focus the Loupe or the real object on display and are the visitors distracted from the real museum objects? What do the visitors learn and remember and are there any prevalent moods and emotions experienced during this thematic visit?

The diversity of the research questions implied the adoption of a mixed-method evaluation protocol in which both qualitative and quantitative data was gathered using a pre-visit questionnaire, observations, a post-visit questionnaire and semi-structured interviews. The participants were invited to participate via two communication channels, the APM "Friends of the Museum" network and the University of Amsterdam student network, alone or with a companion and were informed that they would be thanked for their participation with a free entry for a new visit at the APM. Ethics approval was obtained by the Ethics Committees of the University of Amsterdam and University of Strathclyde.

4.1. *Before and during the visit*

All participants were welcomed by the researchers and taken to a quiet area, adjacent to the gallery room. There, they were informed about the details of the study including the possibility of withdrawing any time without further explanation, then signed the informed consent form. They were then handed the pre-visit questionnaire which contained demographic questions, questions on museum visiting habits and on familiarity with the use of ICT and digital applications and devices. The visitors were then taken to the showcase for which the thematic tour "Children of Zeus" was designed.

Figure 1a-1c. 1a: Two study participants using the Loupe in the Greek Gallery of Allard Pierson Museum. 1b-1c: Loupe close-ups.



While using the Loupe and taking the tour, all visitors were observed and notes were taken using a coded observational template. The template included fields for documenting the order by which objects were visited, the content consulted per object, technical problems encountered while using the device, but also the way visitors allocated their time among the object on display and the relevant content provided by the Loupe. Notes were also taken on whether participants visiting with a companion shared the Loupe and on how they interacted with the objects, with the device and with each other.

4.2. *After the visit*

Immediately after the visit, the participants and one of the researchers went back to the room used for the pre-visit phase, where they were handed the post-visit questionnaire. The post-visit questionnaire was designed to provide answers to the main research questions presented at the beginning of this section. There were thus three distinctive sections. In order to facilitate the presentation of the main findings, a different order than the one used in the questionnaire is consistently employed in all remaining sections. Section C aimed to investigate the utility, usability and ease of use of the Loupe. Section B explored how the visitors perceived the narrative provided through the Loupe and how they self-assessed its potential as an interpretation resource and learning tool. Within both of these two sections, several questions on the topic of distraction and attentional

balance while using the Loupe were included. Finally, Section A, which was handed to visitors immediately after the visit, contained an "Affective Impact" questionnaire. This consisted of two semantic differential surveys, each containing 11 pairs of bipolar adjectives revealing 11 dimensions in emotions or attitudes: one for the Loupe as a device and application, encouraging visitors to rate the "hedonic" qualities (Norman, 2004; Hassenzahl, 2008) of using the Loupe; and one for the story narrated and the content provided using the Loupe. The adjectives were carefully chosen so as to make sense and be identical for both surveys, reflecting emotions and attitudes that are discussed in the relevant User Experience (UX) as well as the Museum Learning literature. There are numerous examples of the use of semantic differential scales in UX studies within the field of Human Computer Interaction (Hassenzahl, 2008; Petrie & Harisson, 2009; Petrie & Precious, 2010; Yusoff et al., 2011), yet –and despite the fact that museums are clearly emotional places- only few examples of their use in the Visitor Studies domain (Bitwood and Thomson, 1987). The 11 pairs of adjectives chosen were the following: uninterested-interested, confused-certain, indifferent-curious, disappointed-pleased, unhappy-happy, bored-excited, discouraged-motivated, unconcerned-captivated, frustrated-satisfied, overwhelmed-in-control and discouraged-inspired. So as to avoid the acquiescence effect, the adjectives were interchanged (from positive to negative and vice versa), and a 5-point scale was used.

After the questionnaire, a semi-structured interview took place. Participants who visited with a companion were interviewed together. One of the participants was unable to also participate at the interview so in overall 15 interviews were carried out. The interview consisted of twelve interview questions addressing issues related to the ease of use and enjoyability of using the Loupe, the perceived learning impact, the issue of distraction and distribution of attention among the Loupe and the objects on display and the content length and quality with a specific focus on the way the visitors used and perceived the text narratives revealed through the Loupe (Van der Vaart & Damala, 2015).

5. MAIN FINDINGS

Though the study conducted used both qualitative and quantitative methods for gathering data, this paper focuses mainly on the findings from the survey and is only augmented with findings from the qualitative data where relevant, i.e. the observations and interviews carried out. On-site paper questionnaires in Dutch were used that were later inputted and analysed using the survey software "Qualtrics". All visitors but two were interviewed in Dutch with all notes and questionnaire comments translated from Dutch to English prior to being further analysed.

In overall 22 adults participated in the study (P1-P22). 10 participants visited alone and 12 in couples during 16 sessions, carried during seven consecutive days with two of the researchers carrying out the field study and gathering the data.

5.1. Participants' profiles

Demographically, the profiles of the majority of the participants were quite similar to the profile of the Friends of the APM, usually older adults, over 60, visiting very often the museum and mainly residing in Amsterdam or a nearby region (source: oral and written communication with APM). Approximately three times more women (n=15) than men (n=7) participated in the study. In terms of age, younger and older visitors were equally well represented with 6 participants for each of the 18-24, 45-54, 55-64 age groups and 3 participants for the over 65 group (14%) but just 1 participant for both the 25-34 and 35-44 age group (%5). All study participants turned out to be frequent museum goers: 73% of the participants (n=16) indicated they visit museums 4 times a year or more with the remaining 27% (n=6) indicating they visit museums 2-3 times a year. When asked which types of educational and interpretation material and resources they use in a museum visit, text came at the first place, with 50% of the participants declaring using text guides, books and brochures. Other popular interpretation resources were audio guides (41%), guided tours (32%) and interactive kiosks and displays (32%). On the lower end, museum websites seem to rarely be used as on-site interpretation resources (18%). In addition, almost a quarter of the participants stated that they do not use any interpretation resources (n=6, 27%). The preference over different forms of text interpretation resources as well as a tendency towards not using any interpretation media has been found to be more popular among frequent museum goers in other studies in the past (Damala, 2009; Damala et al., 2008). These visitors are also known in the literature as "diligent" "motivated", "skilled" or "experienced visitors" (Bitwood and Patterson 1993; Van der Vaart & Damala, 2015). In accordance with consistent findings in the museum studies literature on the nature of museum-visiting as a social activity, two-thirds of the participants stated they usually visit museums with family or friends (n=15), while one-third said that they prefer visiting museums alone. Furthermore, participants were moderately to highly interested in Greek mythology (reflecting the specialist

visitor population of a museum as the APM), with 8 being very interested, 11 just interested and 3 using the midpoint answer (mean 4.63, SD=0.69). This reflects the recruitment via the Friends of the APM, but is also typical of the kinds of specialist museum it constitutes. Despite the fact that the 25-34 and 35-44 age-group were literally non-existent, and despite the low preference for digital interpretative media while engaged in a museum visit, the large majority of the participants stated being confident (n=10) or very confident (n=10) with the use of digital applications and devices, using internet to search, learn or communicate on an everyday basis (n=19).

5.2. Utility and Usability

A subsection of the distributed survey, with nine questions in total, focused on the ease of use, utility, usability and enjoyability of using the Loupe. Most of these questions used a 5-point Likert scale from "Strongly Disagree", "Disagree", over "Neither Agree nor Disagree", "Agree" to "Strongly Agree". Both positively and negatively worded statements were used.

5.2.1. Navigation and Orientation

One of the most important aspects we wanted to test was related with the navigation and orientation within the application as well as within the physical space for which the tour was created. As described in section 3.3, the tour covered one selected showcase, containing 18 objects with content created for 6 of them. The participants thus had to identify one by one the objects for which content was available, then navigate within the content created for each one of the 6 exhibits as described in section 3.3. The statement "The display of the virtual overlays facilitated the identification of the featured objects" was rated with a mean of 4.05 -one of the best scores in this section- with 17 participants agreeing (n=8) or strongly agreeing (n=9), 2 being neutral and only 3 participants disagreeing. Similarly, the negatively worded statement "Identifying the featured museum objects was difficult" gave a mean of 2.45. It therefore seems that the hint given to the visitor in the form of a transparent PNG outline of the artefact and the scene depicted on it did work well as an interaction metaphor for identifying the objects.

Furthermore, the interviews provided useful insights on how the treasure-hunt-like mechanism for triggering the associated with each object content was received by the participants, revealing that many participants enjoyed the search for the matching objects: "It's (also) nice to have to search for objects and to look closely at them" (P10); "Holding the Loupe and searching for the objects added an interesting dimension" (P21 and P22); "holding the Loupe is nice"; "searching for the objects was quite nice" (P2 and P3).

On the negative side during the observations it turned out that a few times, holding and searching for objects with the Loupe sometimes resulted in the system recognizing an object without the visitor realising that. As one of the participants stated during the interviews "it is annoying when the system recognises an object before you do" (P6).

5.2.2. Ease of Use and Intuitiveness

Another important aspect was the ease of use and intuitiveness of using the Loupe and the proposed interaction metaphors. One of the most interesting findings is that the study participants thought that though the Loupe was easy to use, it was not equally intuitive. More in particular, the statement "The Loupe was easy to use" (mean=3.68, SD=1.17) was agreed with more than the statement "Using the Loupe was intuitive" (mean=3.36, SD=1.33). Our onsite observations as well as the interviews corroborated this finding: We observed that most participants would ask assistance from one of the researchers upon picking up the Loupe. After the first interaction with the Loupe, participants would feel much more comfortable and very much at ease with its use. A contributing factor appears to be the limited and clear range of actions the device supports: "(It is) simple, not too complicated; you only need to perform 2 actions, (this is) easy", P10). This finding reflects the differentiation we also find in the literature between intuitiveness (as something being spontaneously and without introduction clear in how to use) and ease of use, which can include learnability and discoverability of functionality. This issue was also discussed by the participants during the interviews. For example, one participant said: "I didn't find the use obvious" (P23). Another one admitted "I was a bit stressed at the beginning, you have to figure out how it works first. After that point, things went well" (P13). A fourth participant stated: "at the beginning, I did not know what to do" (P17). In overall 14 occurrences of comments on the ease of use and intuitiveness were documented during the interviews.

More broadly speaking and apart the "learnability-functionality discoverability" initial stage, participants did not feel uncomfortable while using the Loupe ("Using the Loupe felt uncomfortable": mean=2.64) nor did they think that it was heavy ("The Loupe was heavy": mean=1.82) while the visuals were thought to be of good quality in terms of clarity and luminosity (mean=4.14). On the downsides of using the Loupe, the relatively small size of

the screen was brought up as an issue during 5 interviews. Different ways of interacting with and handling the Loupe were documented during the observations. Participants would mostly hold the Loupe with the right hand, few of them with the left while a couple of participants placed both their hands on the Loupe handle while manipulating it. In shared visits, hand-overs of the Loupe from one participant to another were also registered but in the majority of the cases one of the participants would hold the Loupe while the other one would read aloud and (or) point at the augmented exhibit. Finally, tilting the Loupe to the right to see the next chunk of content, made many participants also slightly tilt their head and body towards the right.

5.2.3. Attentional Balance

One of the main motivations for carrying out this study was examining the question of distraction and attentional balance: during two earlier, informal studies of the Loupe with children in two other museums, little further engagement with the objects – other than finding the exhibits- was observed. Regulating the pace of a treasure-hunt like museum tour via the inclusion of quizzes has been associated with increased engagement and dwell time on museum objects (Astic et al., 2011). However and as discussed in section 2, there is evidence that screen-based museum interactives, be it mobile or fixed-place, are associated with competition or distraction (Grinter et al., 2002; Damala et al., 2008) from the real objects on display. Despite the fact that the Loupe was designed as an AR tangible, it still uses a screen for revealing the narrative to museum visitors.

The relevant finding in our survey proved to be indeed controversial: The statement "Using the Loupe distracted me from the original work of art", scored 3.18, with 7 participants being neutral, 11 agreeing or strongly agreeing and only 4 strongly disagreeing. The analysis of the observational notes revealed that the more experienced our participants were in museum visiting as well as in terms of "reading" and observing objects, the less distracted they were by the Loupe and the more they tended to read or see the content and then look back at the exhibit. However, during the interviews, the more experienced in museum visiting participants were, the more they tended to report back and discuss the distraction and attentional balance issues. Some of them were quite critical: "It was difficult; I was looking at the Loupe a lot, and had less attention of the objects. You don't have to look at the objects while you're reading the story" (P17 and P18); "It's distracting. The information is nice, but I prefer to have time to look at objects" (P7). Visitors also disagreed in their opinion on whether the Loupe made them look more or less at objects. Some felt they looked more at the objects (without it "I would spend less time looking at the objects – 'there's another red-figure vase'; there are so many of those" (P16) or: "I would spend less time, because I wouldn't know the story; that way you're not challenged" (P16). But some thought without the Loupe they would have looked at the objects in a different way (with different questions in mind) or would have looked at other objects: "In a different way, more from my own knowledge; I would try to recognise scenes (and get confirmation from the text label); the Loupe shows you details you didn't notice at first, or that can't be seen; that's its biggest asset" (P17 and P18). Roughly the same number of people thought that without the Loupe they would have looked more (4), less (6) or in a different way (5) at the objects.

With the interviews and the survey providing mixed evidence, it is the observations that revealed that some types of content prompted the large majority of participants to look back at the exhibits, substantially increasing the dwell time on them, else the time the visitors spent contemplating a real museum artefact. More specifically and according to our observation notes, at least 17 out of the 22 participants (~77%) switched their attention so as to examine and scrutinize a statuette from Boeotia, Greece dating back to the 4th century BC, depicting Europe at the moment where she is abducted by Zeus who has taken the form of a white bull (inventory number APM01005, Figure 1b). A low-fidelity animated GIF showed the original colours the statuette was painted with, while the content (the short phrase which was part of the narrative) invited the visitors to look back to the artefact so as to see if they can see any traces of the original colours.

Most importantly and despite the average obtained for the "distraction-attentional balance" question, 19 out of 22 participants agreed (n=6) or strongly agreed (n=13) when they were asked whether they would consider using the Loupe, should it be available in a museum, giving a mean of 4.41 which was also the highest mean observed for this section of the survey (SD=0.85).

5.3. The Loupe as a learning offer

An important goal for this iteration of the Loupe was to provide a short, meaningful, thematic tour with a clear, educational narrative and storyline, able to be followed by the visitors all by favouring their engagement with the topic narrated and the objects on display. Measuring and assessing learning is considered as notoriously difficult (Diamond, 1999) particularly concerning adults (Donald, 1991) so for this

section of the survey we tried to: a. test what visitors thought about the overall content length and quality, b. invite the participants to a self-assessment of what they achieved during the visit. The survey questions were thus roughly equally divided to cover both aspects.

We wanted to find out whether the 6 exhibits included in this thematic tour were felt to be adequate. Half of the participants thought that the objects were neither too few nor too many, 8 participants thought there were few objects while only 3 thought that there were too many (mean=2.82). The overall duration of the tour (+/- 15 minutes) was also judged satisfactory: the mean obtained was 2.95 with 14 out of the 22 visitors judging the duration as ideal, another 4 saying that more content could have been included and another 4 rating the duration as longer than ideal. We should however take under consideration the profile of these visitors, which we characterized as "experienced visitors"; this might have contributed to obtaining higher scores as in comparison with participants less experienced in museum visiting.

The second set of questions investigated the learning potential of the thematic tour presented through the Loupe as an educational prototype and AR application. These asked from participants to provide subjective ratings using a 5-point Likert, "strongly disagree" to "strongly agree" scale for statements reflecting some of the desired learning outcomes set during the design and content-creation process. We were interested in finding out whether the role and primary function of the featured in the tour objects - 4 ceramics and 2 statuettes- became understandable; 18 out of the 22 participants agreed (n=10) or strongly agreed (n=8) with the relevant statement with 4 being neutral (mean=4.18, SD=0.73). We also investigated whether the iconography of the featured objects became clear as a result of having taken the tour. 19 out of the 22 participants agreed (n=6) or strongly agreed (n=13) with the statement "Using the Loupe assisted me to understand what was represented in the depicted objects" (mean=4.36, SD=0.95)). Furthermore all study participants but one agreed (n=7) or strongly agreed (n=14) when asked whether they consider they learned at least one thing they did not know (mean=4.55, SD=0.74), while 20 out of the 22 asserted that they recalled at least one thing they had learned in the past (mean=4.59, SD=0.67). As one of the participants put it, one of the reasons for which he appreciated the tour was that "some things were unknown while other things, already known, came back to surface" (P18). In sharp contrast, the broader and more audacious statement "my understanding of Greek Mythology extended", gave a mean of 3.87 that- though quite high- is the lowest one obtained in this section. This can be probably attributed to the limited number of exhibits included in the tour in combination with the profile of the study participants as experienced visitors. Finally, on a 10 point Likert scale most participants were likely to want to find out more about Greek mythology in the future (mean 7.73, SD 1.64), with no correlation found between the pre-visit questions which invited the participants to assess on a scale of 1 to 10 their interest in Greek mythology.

It would be interesting to bring in this picture some of the answers provided by the participants during the interview where they were asked what the most memorable thing they saw or encountered was and what was their favourite exhibit. As discussed in section 5.2.3, the statuette of Europe and Zeus proved to be particularly popular among the study participants inviting them to take time and look closely; as already explained the relevant content (both the text and the animated GIF) seemed to intrigue the interest of the visitors and make them look back at the exhibit. Having to look back in order to discern the original colours was repeatedly reported back by many study participants during the interviews: In total, in all 15 interviews, there were no less than 10 occurrences of Europe as the participants' favourite object and most memorable object they encountered during the tour. As stated by one of the participants, "the reference to the colours of Europe, was a trigger to look at the statuette more closely" (P17 and P18). Other visitors seemed to be making connections with already acquired knowledge: "seeing the colours was interesting, we see statues and statuettes as white, but they used to be colourful, it is nice to see that" (P6). Providing a way to show or add different dimensions at the interpretation layers that may surround an exhibit was brought up during the interviews by several participants. The drinking bowl featuring Apollo that was accompanied by the sound clip reproducing how an ancient harp would sound like, proved to be another "favourite" as well as "memorable" object. One participant said: "I liked the music (sound clip), I didn't have any clue what the instrument would sound like" (P11 and P12). A common characteristics of these two objects– rated as memorable and favourite objects by the participants- are not just that a different type of medium was available in the tour (an animation and audio clip respectively) but that the content and its form and structure invited them to look back and explore the real exhibits all by adding or augmenting the objects with a different "dimension", a quality for which AR applications have been praised.

Another important and interesting finding was that the guidelines and strategies used while work-

ing with text, to provide concise, short and inviting text narratives had their impact on the visitors. A recent analysis (Van der Vaart & Damala 2015) of the relevant findings demonstrated that the large majority of participants not only read the text but were also quite sceptical as to whether they would have read the same amount of text had it be administered to them via a booklet or a label ("I'm more inclined to read the texts this way, in comparison to text labels", P21-P22). This is an exciting finding indicating that sometimes simple types of more traditional media, e.g. text, can work very well alongside digital learning –including AR- approaches.

5.4. *Affective Impact*

It has been said that in providing meaningful and rewarding museum visiting and learning experiences, an "enjoyment" parameter should be considered as important as "learning" (Perry, 1993; Hooper-Greenhill, 2004). However, despite the fact that more and more scholars emphasize that cognitive knowledge (such as information and facts) cannot be separated from affective knowledge, (perceived as emotions, feelings or values) (Hooper-Greenhill, 2004), there are still surprisingly few things we know about the role of emotions in learning. Yet, more and more studies and research seem to indicate that each and every single memory comes with an emotional stamp attached to it (Damasio, 2008) and that the "stronger the emotional value, the more likely sensory information is to pass the initial inspection and pass into memory" (Dierking, 2005). More broadly speaking, learning in informal learning environment is found to be more effective if it is "personally rewarding, emotionally satisfying and freed from negative mental states while providing both choice and control over learning" (Dierking, 2005; Falk and Dierking 2000). With this rationale, we dedicated the first section of the survey to an "affective impact" questionnaire that would allow us to investigate the emotional engagement of the participants both with the Loupe as a tangible device as well as with the content and narratives revealed.

As detailed in section 4.2.1, after a careful selection, 11 set of bipolar adjectives, representing 11 dimensions, were used twice. The first instance invited the participants to rate to which degree they experienced any set of bipolar adjectives-dimensions while using the Loupe, the second instance invited them to rate with the same way the narrative and contents provided. Our hypothesis was that any score close to the midscale, i.e. 3, would be difficult to interpret since it would be impossible to know whether this means absence of the bipolar adjective encountered or a neutral attitude towards it. While within the survey the set of adjectives were interchanged from positive to negative and vice versa, during analysis all adjectives were inversed and analysed from negative to positive.

Table I. Affective Impact Questionnaire: values obtained for the Loupe for each of the 11 dimensions

The Loupe (Σ=22)	Min Value	Max Value	mean	SD (σ)	var(X)
Uninterested : Interested	4	5	4.55	0.51	0.26
Confused : Certain	1	5	3.68	1.09	1.18
Indifferent : Curious	1	5	4.55	0.91	0.83
Disappointed : Pleased	3	5	3.77	0.69	0.47
Unhappy : Happy	3	5	4.18	0.73	0.54
Bored : Excited	1	5	4.27	1.08	1.16
Discouraged : Motivated	2	5	4.23	0.92	0.85
Unconcerned : Captivated	1	5	4.00	1.23	1.52
Frustrated : Satisfied	2	5	4.14	0.83	0.69
Overwhelmed : In-control	2	5	3.59	0.96	0.92
Discouraged : Inspired	2	5	3.91	0.87	0.75

Some first interesting findings emerged. The first one is that all pairs of adjectives appeared to perform well, that is, were rated on the positive side. The two sets of adjectives with the highest score for both the Loupe and the Content composites were obtained by the set of adjectives "uninterested-interested" (Loupe mean=4.55, Loupe σ=0.51; Content mean=4.41, Content σ=0.73) and "indifferent-curious" (Loupe mean=4.55, Loupe σ=0.91; Content mean=4.41, Content σ=0.73). Interest and curiosity are two key notions widely discussed in the literature for their potential in creating and sustaining rewarding museum visiting experiences. Within the context of formal learning environments, the notion of "interest" (both situational and individual) has been discussed as early as 1913 by Dewey (Dewey, 1913). More recently it has also been discussed by Csikszentmihályi as a basic component of the theory of flow but it has also been related with the notion of attention which is crucial for the capture, focus and engagement of visitors (Bitwood 1993; Bitwood, 2013;). Curiosity, on the other hand, has been defined as the "likelihood of investing psychic energy in novel stimuli" (Csikszentmihalyi and Hermanson, 1999) and has been linked with visitors' agendas and their expectation "to be exposed to phenomena and objects that they might not encounter or approach in different settings" (Perry, 1993). Capturing visitors'

curiosity has also been identified as the first step in the process of catering for intrinsically motivated learning with the second step being sustaining interest for the very same exhibit a visitor has approached. (Rounds, 2004). It is therefore noteworthy that the notions related to both interest and curiosity came on top of visitors' preferences, among a set of 11 in total sets of different dimensions. Other dimensions that performed well both for the Loupe and the Content were the "bored-excited" (Loupe mean=4.27, Content mean=4.09), "discouraged-motivated" (Loupe mean=4.23, Content mean=4.05), "unhappy-happy" (Loupe mean=4.18, Content mean=4.14) and the "frustrated-satisfied" (Loupe mean=4.14, Content mean=4.09) dimensions. Table 1 provides an overview of the values we obtained for the Loupe composite in the Affective Impact questionnaire.

A comparison of the results obtained for the Loupe among the three age groups that happened to be composed by 6 participants, reveals that the 18-24 felt mainly "excited", "interested" and "captivated" by the Loupe, the 45-54 felt "curious" (mean=5, σ=0), "interested" and "motivated" while the 55-64 group felt "curious", "captivated" and "interested" by the Loupe. Though all 11 dimensions were rated on the positive side both for the Loupe as well as for the Content, the participants were slightly more "motivated" and "inspired" by the Loupe as in comparison with the Content, slightly more "inspired" and "in-control" of the content as in comparison with the Loupe and equally "interested", "curious", "pleased" and "satisfied" by the Loupe as a tangible device as well as by the Content. Interestingly, female respondents expressed themselves stronger than male participants with lower minimum values and higher maximum values observed as well as higher means for all set of adjectives.

6. DISCUSSION & LESSONS LEARNED

Our research design sought to explore the potential of a tangible and AR-enabled interactive for learning to look at Ancient Greek art and relevant museum artefacts. Our study showed that the AR-enabled "treasure-hunt", mechanism for identifying the augmented exhibits that were included in the narrative appealed to the study participants and facilitated navigation and orientation both in the physical space and the application. Most importantly, both the AR and Loupe interaction metaphors – as well as their potential- were grasped, understood and commented by the study participants who often evoked and discussed features related with the Loupe's nature as a museum interactive tangible. These findings seem to provide an argument for the potential of tangible interaction while engaged in digital learning and edutainment activities in informal learning environments. However and as discussed in the relevant literature, our study also showed that ease of use does not necessarily go hand-in-hand with intuitiveness: a disjunct was found between ratings of intuitiveness and ease of use, as participants needed to be shown how to use the Loupe first, and then quickly found it easy to use. Prior work in HCI and tangible interfaces (Hornecker 2010) has pointed out that with computational devices, there is always some learning involved for using them, and that the key is in supporting this learning process. In these cases, easy, straightforward interaction metaphors may become a serious parameter for improving and facilitating the learnability of a device or an application. Interestingly, though the observations showed that the more experienced in object "reading" our participants were, they more they looked back at the real object on display and the less distracted they were, it was also the very same participants that reported being distracted by the Loupe while engaged in the tour. Despite this pattern the large majority of the study participants, including some of the most critical as to the distraction-attentional balance issue, stated that they would adopt and use the Loupe should it be available among the permanent learning offers in APM.

Regarding the value of the Loupe as a learning offer, the analysis of the "learning impact" questions in conjunction with the analysis of the interviews' findings seems to indicate that the overall acceptance of the Loupe and the AR tour "Children of Zeus" is related both with the design and tangible interaction metaphors and affordances of the Loupe as well as with the carefully devised and structured content that was used for creating the tour: using an overarching narrative, short and easy to read text phrases, "cliff hangers" as well as short phrases in the form of questions – all inviting the visitors to look back at the objects- worked well both for all included objects individually as well as for the overall narrative revealed through the Loupe. At the same time, it is probably not a coincidence that the two most memorable and successful objects, the statuette of Europe and Zeus the drinking bowl on which Apollo was depicted playing the lyre, also contained simple yet non-textual content (in the form of an animated GIF and a sound clip) that either revealed a different dimension or rendered the invisible visible, as mentioned by several study participants who also commented on how the content types and structure prompted them and invited them to look back the real objects on display.

In addition to exploring the potential of this tangible, AR-enabled museum interactive, an additional contribution of our field study is establishing that

museum learning with digital resources is multifaceted and multidimensional, namely a process which is as much cognitive as much as affective, with interest and curiosity appearing to be the most predominant factors both for triggering and for maintaining visitor engagement. Clearly some of our findings – as the fact that women tend to express themselves stronger as in comparison with men regarding moods and feelings experienced while visiting -need further investigation but we feel it is safe to say that cognitive engagement is as much prevalent as emotional engagement in creating meaningful and rewarding digital learning experiences for Cultural Heritage contexts inviting all senses.

7. CONCLUSIONS AND PERSPECTIVES

With regards to the of validity, reliability and generalisability of the study findings it is important to keep in mind that our sample randomly turned out to consist of frequent museum goers or experienced museum visitor, though to different degrees. It would be interesting to repeat the study with less experienced visitors and compare the findings.

Other issues could also benefit from further research: as the thematic tour implemented covered one showcase, one interesting question is explore how to set-up mechanisms and techniques that could guide the visitor from one showcase to another or even from one gallery to another (i.e. from the Roman to the Ancient Greek Gallery). Similarly, some of our survey questions need further clarification: was the number of exhibits judged as satisfactory per showcase or as a standalone tour? There are indications that -given our participants museum visiting habits- the former seems to be the case. Furthermore and during the process of the research-design another interesting direction for a follow-up study was constantly present: carry out a comparative evaluation study using the very same objects, texts and narrative through a simple yet attractive text brochure so as to be able to compare the results and correlate them with the very form, nature and embodiment of each interpretation resource, in this case the Loupe and a text brochure.

In the meanwhile, a new iteration of the Loupe (co-supported by the meSch project) was recently implemented for the Hunt Museum in Limerick, Ireland; this new iteration it will assist in further understanding and establishing the potential of tangible –and in this case AR-enabled interaction- as a viable learning offer that can meaningfully assist, guide and engage the visitors throughout their museum visit.

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