



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 on museum objects and artefacts? Or do they distract and take away the attention from the real museum objects on display? We present the Loupe, a tangible Augmented Reality prototype in form of a magnifying lens, which allows 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. An evaluation study with 22 adult participants was carried out, using both qualitative and quantitative evaluation methodologies, so as to explore the utility and usability of the Loupe as well its learning and affective impact. Our findings suggest that the acceptance of the Loupe as a museum interactive and learning resource, was related both with its qualities as a tangible as well as with the structure of the content and the narratives revealed.

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

1. INTRODUCTION

Museums and Cultural Heritage institutions worldwide 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 interactive installations to 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 visitors 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 resulting in 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 prototype offers a limited and well-defined set of interactions that allow visitors to explore museum artefacts. For this study, a thematic tour was implemented in Allard Pierson Museum (APM) using a “scavenger hunt” approach (Astic *et al.*, 2011). The visitor holds the Loupe upright, receives a hint 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, then searches

for the next object included in the thematic tour (Figure 1a-1c).

Embedding interactive screen devices (O’Malley, 2004) -nowadays iPhones, tablets, androids- is one of the established strategies in developing and prototyping tangible interfaces. The Loupe is one of several exploratory prototypes created in the first year of the meSch EU project (Material Encounters with Digital Cultural Heritage) which explores the potential of co-designing novel platforms for the creation of tangible exhibits at heritage sites (Petrelli *et al.*, 2014).

This paper presents the main findings of an evaluation study we carried with the Loupe prototype, conducted with 22 randomly chosen adult participants. Section 2 provides the rationale and motivations underlying the design of the Loupe as an AR tangible for museum visiting. Section 3 elaborates on the underlying requirements and the design of the Loupe which also influenced the content creation process. Section 4 describes the evaluation protocol 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 a tangible device and as an educational resource for museum visiting. Section 6 resumes our main conclusions as well as current limitations of our approach, 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. Screen-based technologies in particular (this concerns mobile devices and large screens alike) tend to be ‘attention-grabbers’ that risk distraction from the original artefacts (Bannon *et al.* 2005; Pujol-Tost 2011; Macleoad 2013; 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 (Hornecker, 2012). 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 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.

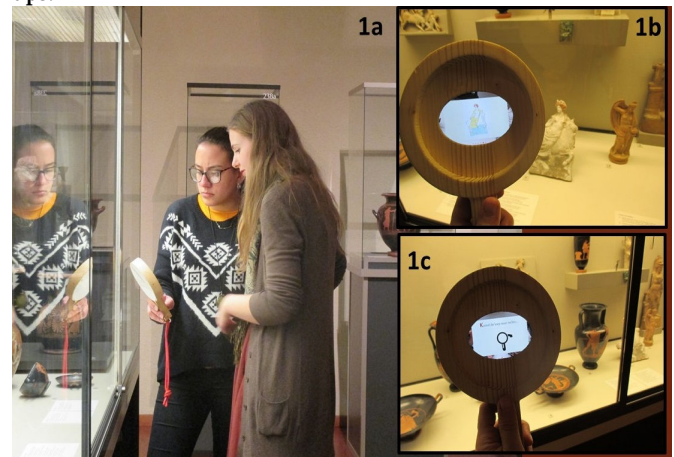
The Loupe was imagined after a workshop session at the APM using the co-design approach which has been adopted within the meSch project (Ciolfi et al., 2016). During the workshop session, a number of early interaction ideas were tested with cultural heritage professionals. To be able to evaluate the ideas, paper prototypes were developed by Waag Society, a design institute for art, science and technology and one of the meSch project partners. One of those ideas (Diaz et al., 2015) 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 advantages of AR applications, was something that was evaluated as a promising route, but the monocular idea was discarded as an activity only suitable for individuals, 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 (for the very first iteration of the Loupe prototype see: <http://mesch-project.eu/mesch-prototype-the-loupe>). 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. Furthermore, 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- with the right physical object, relevant content is displayed. The visitor can tilt the Loupe to the right to move on as the embedded sensors of the iPhone are able to detect motion.

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



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 with the Loupe (tilting the Loupe right to go forward, tilting left to go backwards); 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/>). The 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. The considerations which led to the selection of the museum artefacts and the content are described in the following section.

3.3. Loupe Narrative and Content Creation

One of the key requirements of APM was to create an AR prototype that would allow fast and easy in-house content creation and update, using simple media such as text, simple 2D images and sounds which is familiar for museum curators (van der Vaart & Damala, 2015) instead of favouring rich 3D visuals. We also had to identify suitable objects within the museum galleries for the 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. This would enable an easy and robust identification.

Furthermore, two earlier informal, validation studies with the Loupe in APM had shown us that visitors struggled to identify individual objects 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, visitors found extremely challenging the identification of the next object in the AR tour, when this was located in a different display case than the object they had previously engaged with.

Therefore, we decided to move a scale down and create an AR tour for one display case using the Loupe to provide content that would connect selected artefacts and reveal a clear narrative linking all selected objects. Taking all these requirements into

account, we decided to use one display case labelled "Gods and Heroes" containing artefacts depicting various Greek gods and heroes, situated in the permanent exhibition of the Greek gallery. The main narrative on which we focused evolved around the various affairs king of the gods Zeus had with goddesses and mortal women alike and the 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 both women and children, whenever she discovered her husband's betrayal.

Since the size of the Loupe's screen was limited the first draft of text was written in short phrases resembling a series of "tweets". Several images and one short piece of lyre music were identified by the Greek Gallery museum curator. Another set of images created from scratch by the curator were turned into a simple GIF image animation. 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 (Ekarv, 1999), 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. Its size made that: a. the text had to be provided in short sentences, using simple sentence structures; b. the narrative for each object had 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 for each object that was included in the tour. In order to hold visitors' attention, which is selective and limited, but also has focusing power, the text was made more salient by using so called "cliff hangers" in the short segments of texts, encouraging visitors to read on (Bitgood, 2000). Finally, to help visitors balance their attention between reading text and looking at the objects, the texts included questions prompting the visitors to focus on the physical appearance and on details that were of visual interest (Bitgood & Patterson, 1993; Bitgood, 2000): several introductory phrases encouraged the visitors to look the objects so as to find out whether they recognized the figure they were looking at ("What are you looking at?", "Can you recognize the figure?").

In its final form, the thematic tour "The Children of Zeus" included 6 objects (among the 18 objects of the showcase), 4 ceramics and 2 statuettes. The accompanying text consisted of an average of 7 "pages" or short text phrases per object. For 5 out of the 6

objects, other simple content forms - images, an animated GIF and a sound file- were also present.

Within the Greek Gallery of APM, a stand was installed from which the visitors would pick up the Loupe in front of the showcase “Gods and Heroes” (Figure 1a). Upon the surface of the stand, short text instructions were available on how to use it the Loupe. 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 (van der Vaart & Damala, 2015).

4. EVALUATION QUESTIONS

The design principles, requirements and motivations presented in the two previous sections assisted in formulating the main questions we sought to explore during the field study. The main issues we tried to tackle while planning the evaluation 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 approach 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 through social media, alone or with a companion. Ethics approval was obtained by the Ethics Committees of the University of Amsterdam and University of Strathclyde.

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. Demographically, the profiles of the participants turned out to be quite similar to the profile of the Friends of the APM: adult visitors, visiting museums very often (3 to 4 or

more than 4 times a year), residing in Amsterdam or a nearby region.

4.1. Before and during the visit

All participants were welcomed by the researchers and informed about the details of the study, including the possibility of withdrawing any time without further explanation. They then signed an informed consent form and were handed the pre-visit questionnaire which contained questions on demographics, museum visiting habits and ICT usage habits. The visitors were then taken to the showcase for which the thematic tour “Children of Zeus” was designed.

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 content consulted per object, the way visitors allocated their time among the object on display and the relevant content provided by the Loupe as well as technical problems encountered while using the device. 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

After the visit, the participants were handed a post-visit questionnaire. The post-visit questionnaire was designed to provide answers to the main research questions presented at the beginning of this section. Thus, in addition to the questions included in the pre-visit questionnaire, three more sections, section A, B and C were present in the post-visit questionnaire raising the total number of questions included in all sections of our pre- and post-visit questionnaire to thirty-one. As we wanted to minimize any effect of visitors’ fatigue, the most “demanding” in terms of cognitive effort sections of the post-visit questionnaire were presented first. However, in order to facilitate a concise presentation of our main findings, we present each section’s findings in the exact reverse order as in comparison with the way the sections were ordered for the study participants.

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 interpretive and learning resource. 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” survey, containing 11 pairs of bipolar adjectives reveal-

ing 11 dimensions in emotions or attitudes. The participants had to fill this template twice: once for “judging” the Loupe as a museum tangible and once for the content revealed through the Loupe. This part of the questionnaire aimed to encourage visitors to rate the “hedonic” qualities (Norman, 2004; Hassenzahl, 2008) of the prototype and of the narrative revealed. The adjectives included reflected emotions, attitudes moods that are discussed in the relevant User Experience (UX) as well as the Museum Learning literature. They also made sense for both aspects we were interested in examining, i.e. moods and feelings associated with the use of the Loupe as a tangible as well as moods and feelings associated with the content and the narrative revealed. There exist numerous examples of the use of semantic differential scales in UX studies within the field of Human Computer Interaction (Hassenzahl, 2008; Petrie & Harisson, 2009; 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 (Bitgood 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.

The participants had then to fill in Section B (learning with the Loupe) and Section A (utility and usability). After filling in all sections of the questionnaire, a semi-structured interview took place. Participants who visited with a companion were interviewed together. One of the participants was unable to 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 narrative (Van der Vaart & Damala, 2015).

5. MAIN FINDINGS

Though the study conducted used both qualitative and quantitative methods for gathering data, this paper focuses on the findings from the survey which are backed-up with findings from the qualitative data, 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.

5.1. Participants’ profiles

Approximately three times more women (n=15) than men (n=7) participated in the study. In terms of age, we had 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 interpretive 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” (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 mostly visited 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 mid-point 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 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. The observations provided additional evidence as to the efficiency of the transparent object outline as a hint and interaction metaphor for identifying the objects. This feature was also mentioned as something enjoyable by some of the participants during the interviews: "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).

However, and as we also observed, during the phase of familiarisation with the Loupe, moving in front of the showcase while holding the Loupe upright might result 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 on-site 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 an important differentiation between intuitiveness as something being spontaneously and 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 down-sides 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.

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 (Astic *et al.*, 2011) via the inclusion of quizzes has been associated with increased engagement and dwell time (vom Lehn and Heath, 2005) on museum objects. 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 (“I would spend less time looking at the objects”, P15) or: “I would spend less time, because I wouldn't know the story” (P16). But some thought that 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 (n=4), less (n=6) or in a different way (n=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, (i.e. the time the visitors spent contemplating a museum artefact). More specifically and according to our observation notes, at least 17 out of the 22 participants switched their attention so as to examine and scrutinize a statuette, depicting Europe at the moment where she is abducted by Zeus who has taken the form of a white bull (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. Learning

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 in informal learning environments is considered as notoriously difficult (Diamond, 1999) particularly concerning adults (Donald, 1991; Falk *et al.*, 2014) 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.

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 text and the animated GIF intrigued the interest of the visitors inviting them to look back at the exhibit. Having to look back in order to discern the original colours was repeatedly reported back by many study partici-

pants 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 during an interview with two visiting companions, “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). 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 characteristic 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 has been praised.

Another important and interesting finding was that the use of short text phrases which were both concise and inviting had considerable impact on the visitors. A recent analysis (Van der Vaart & Damala, 2015) of the data 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 and that the “stronger the emotional value, the more likely sensory information is to pass the initial inspection and pass into memory” (Damasio, 2006; 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” (Falk and Dierking, 2000). With this rationale, we dedicated the first section of the survey to an “affective impact” survey 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. The study participants had to complete this template twice: the first occurrence of the survey, invited the participants to rate to which degree they experienced any set of bipolar adjectives-dimensions while using the Loupe. The second occurrence 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 dimension revealed by its bipolar set of adjectives or simply 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. 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 (Bitgood 1993; Bitgood, 2013;).

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

The Loupe ($\Sigma=22$)	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 : Hap- py	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

Curiosity, on the other hand, has been defined as the “likelihood of investing psychic energy in novel stimuli” (Csikszentmihályi 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 survey.

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.

The findings which emerged using the affective impact survey are extremely interesting and will be further validated with a much larger sample on the occasion of two forthcoming temporary exhibitions in the Netherlands, in Museon and Allard Pierson Museum, which will fully integrate several meSch components and artefacts.

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, 2012) 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 findings from the relevant section of the questionnaire, 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 with its design, the tangible interaction metaphors and affordances 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 which invited the visitors to look back at the objects, worked well both for the overall narrative and each object included in the “Children of Zeus” tour. At the same time, it is probably not a coincidence that the two most memorable and successful objects, the statuette of Europe and Zeus and the drinking bowl on which Apollo was depicted playing the lyre, also contained non-textual content -an animated GIF and a sound clip respectively- that either revealed a different dimension or rendered the invisible visible. Several study participants 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 visitors. Further validation is needed to find out if these findings apply to less experienced visitors too.

Other issues could also benefit from further research: as the thematic tour implemented covered one showcase, one interesting question is exploring 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, 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 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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