The MIT Museum Glassware Prototype: Visitor Experience Exploration for Designing Smart Glasses

MARCO MASON, Marie Curie fellow at the: School of Museum Studies, University of Leicester, Leicester, UK; Program in Science, Technology, and Society, Massachusetts Institute of Technology, Cambridge, MA, USA

With the growth of enthusiasm for the adoption of wearable technology in everyday life, the museum world has also become interested in understanding whether and how to employ smart glasses to engage visitors with new interpretative experiences. The growing interest in wearable technology encourages experimentation with smart glasses, as this trend is going to influence digital media interpretation for museums in the near future. To explore the use of smart glasses in the museum, a Glassware prototype was designed and tested through a field experiment that took place at the Robotics Gallery at the MIT Museum. During the experiment, I observed and then interviewed participants. Finally, I analysed the data following a qualitative research approach. The findings of this study have to be seen as an initial contribution to the design of latest generation of smart glass apps, providing reflections for further studies and projects.

Categories and Subject Descriptors: C.5.3 [**Microcomputers**]: Portable Devices; H.5.1 [**Multimedia Information Systems**]: Artificial, Augmented, and Virtual Realities

General Terms: Wearable technology; visitor experience; cultural heritage; smart glass; design

Additional Key Words and Phrases: Museum, augmented reality, Google Glass

ACM Reference Format:

Marco Mason. 2016. The MIT museum glassware prototype: Visitor experience exploration for designing smart glasses. J. Comput. Cult. Herit. 9, 3, Article 12 (July 2016), 29 pages.
DOI: http://dx.doi.org/10.1145/2872278

1. INTRODUCTION

The Google Glass is amongst the main technological novelties of the last two years and, at the same time, one of the most controversial. According to Google Glass analysts, the delay of its arrival on the commercial market created uncertainty about the possible large adoption of this particular wearable technology [Wohlsen 2014a; 2014b]. Whether or not the actual Google Glass wearable device will be on people's faces in the near future, it is undeniable that there is great attention upon, and growing interest in, the adoption of wearable technology such as smart glasses [Wasik 2013; Hammersley 2014]. Museums are not excluded from this debate [Stimler and Stein 2014; Gallagher 2015; May 2015; NMC

This work is supported by the Widget Corporation Grant #312-001.
Q1 Author's address: School of Museum Studies Bldg. University Road 19, Leicester LE17RF, UK.

DOI: http://dx.doi.org/10.1145/2872278

Horizon Report 2015 Museum Edition]. In the recent report published by the Center for the Future of Museums, *Trendswatch 2015* [Merrit 2015], wearable technologies such as smart glasses are described as a "logical extension of BYOD" (Bringing Your Own Device), which can offer curators and educators new opportunities for museum interpretation that are not offered by hand-held technology.

As a result wearable devices such as Google Glass are worthy of being an object of research within museums in order to better understand their potential and limits. The aim of this article is to explore the use of smart glasses[1] in the museum context in order to provide insights into opportunities to consider when designing for smart glasses as part of the everyday museum experience.

Based on these premises, I conducted a research *through* design investigation [Stapper 2007; Findeli et al. 2008] where an artifact (e.g., a prototype) played a crucial role in building new knowledge [Chamberlain et al. 2007; Joep 2007]. I opted for a field research experiment based on qualitative analysis of the visitor experience [Richards 2009], resulting from the observation and interview of visitors who had tested a Glassware[2] working prototype for the MIT Museum Robotics Gallery. Taking a button-up approach helped me to consider what really matters to visitors, beyond pure functionality [Hassenzahl et al. 2010]. The findings which emerged are presented here and then compared with existing literature that draws from the theoretical background of technology for mobile learning in cultural heritage settings, wearable technology, and Augmented Reality (AR).

This article provides insights for the design of smart glasses for cultural heritage settings by presenting and discussing findings gleaned from the exploration through the observation – and following interviews – of people who used the Glassware prototype during the experiment. This research can be beneficial for museum practitioners, designers, and developers because it (a) contributes to a better understanding of the aspects and experiences that a new technology such a smart glasses might engender for people visiting a museum [Koskinen et al. 2011] and (b) links to significant literature in the field of Wearable Computing, in particular smart glasses and Augmented Reality for cultural heritage.

2. WEARABLE COMPUTING AND SMART GLASSES

Wearable computing refers to any electronics that can be worn or even implanted in the body. The sophistication and miniaturization of technology have produced small and powerful computers which favour the creation of new technology that permits many different features in a relatively limited size of device [Lucero et. al 2013]. There are different types of wearable technology available to the public [Sung 2015]: wrist bands, smartwatches, smart clothing, smart jewellery, and head-mounted displays. Future scenarios may see wearables even residing inside our body, thanks to (or because of) the next big frontier of implantable wearables [Schumacher 2014; de' Medici 2015].

Wearable technology in general is gaining momentum. According to predictions, the wearable technology market – including smart glasses – will exponentially increase in the next five years [Pedersen 2013; Chauhan et al. 2014]. As result, wearable technology will be more and more present in museum settings as confirmed by digital media trends for the next few years [Merrit 2015]. The possible adoption of wearable technology opens up a new conundrum for museums and digital heritage on how to engage visitors through new interactions and experiences. In particular, interactive glass devices have recently generated growing interest, and the museum world is paying great attention to the use of smart glasses in museums for enhancing the visitor experience [NMC Horizon Report 2015 Museum Edition].

[1] In this article the terms smart glasses, see-through head-mounted displays, interactive glass devices are used interchangeably.
[2] Google defines Glassware as "apps and services designed especially for Glass, built with Glass design principles" (https://developers.google.com/glass/). Generally speaking, the Glassware is the equivalent of an app for a smartphone.

Fig. 1. Chios Kore in CHESS – Augmented Reality Stories at Acropolis Museum. Credit: http://www.chessexperience.eu, Copyright © 2011-2016, the CHESS Consortium.

In this article, I focus on Google Glass (as an optical headset that is worn like a pair of eyeglasses) and particular attention is paid to the concept of Augmented Reality (AR). AR is a particular form of mixed reality [Milgram and Kishino 1994; Ohta and Tamura 1999] that aims to enhance user's experience through the three-dimensional integration of digital information with the physical context in real time [Rattanarungrot and White 2014; Van Krevelen and Poelman 2010; Kiyokawa 2012]. Azuma [1997] defined three underlying characteristics of any AR application: (1) combining the real and the virtual; (2) being interactive in real time; and (3) being registered in 3D. Researchers have already investigated the potential of integrating AR in mobile multimedia for museums (Figure 1), showing that "Augmented Reality visualizations can provide extremely meaningful insights when applied in archaeological or historical parks or museums" [Damala et al. 2007]. Several studies on AR with museums have described the potential benefits of this form of interpretation in cultural heritage, in terms of: technical challenges [Boyer and Marcus 2011; Van Krevelen and Poelman 2010; Rattanarungrot et al. 2014]; interaction techniques [Keil et al. 2013]; visitor engagement [Barry et al. 2012; Tillon et al. 2011; Keil et al. 2014]; personalization of the museum visit [Damala and Stojanovic 2012; Rattanarungrot and White 2014]; tools to enable the artists to "augment" their painting with dynamic content [Lu et al. 2014]; assessment underlining the contribution of AR in museum interpretation and its educational implications [Tillon et al. 2010]; and the opportunity to bridge the gap between the digital and the physical [Damala et al. 2008].

This body of research has recently started to inform studies that adopt optical see-through head-
Q4 mounted displays. For example, ARtSENSE is a research project that used AR see-through glasses in a cultural heritage context, studying a kind of interpretative system that combined visual, audio, and physiological sensors to create a personalized experience where visitors could receive tailored content [Damala et al. 2012].

However, in particular for the Google Glass, there are very few academic research papers that have explored the potential of this device in cultural heritage settings. Further research is required. The Manchester Metropolitan University has recently conducted a study on Google Glass to explore how "visitors will benefit from augmented information while looking at museum artefacts" [Leue et al. 2015] by adopting the General Learning Outcomes (GLO) framework [Hooper-Greenhill et al. 2003] to examine the impact of this hands-up device on learning experiences within an art gallery. The results indicate how Google Glass can offer interesting opportunities to facilitate the learning experience.

The commercialization of this technology and the consequent drop in its price has opened up the possibility of experimentation beyond specialised research centers (especially located within universities), offering the possibility for museums to carry out pilot projects, develop smart glass applications, and test them in-house with their visitors. As result, cultural institutions have recently started experimenting with smart glasses and explorations with Google Glass have been conducted, outside the academic context, directly by cultural institutions. Even if they are not documented by academic and research-oriented publications, I consider it appropriate to mention these pilot projects, especially considering the scarcity of material available at this moment.

In November 2013, the Museo Egizio in Turin presented the pilot project Googleglass4lis,[3] a solution that allowed deaf people to have access during their entire museum experience through the use of Google Glass [Museo Egizio 2013]. In June 2014, the Bard Graduate Center Gallery in New York City launched its Google Glass Exhibition Interpretation Pilot Project to experiment with new ways of enhancing visitor engagement by developing an app that used image recognition technology [BGC Google Glass Team 2014; BGC 2014]. In December 2014, the Imperial War Museum, London [Willshaw 2014] held an experiment to see how the First World War Galleries could be enhanced with the use of Google Glass.[4] They used Google Glass devices jointly with iBeacon sensors, which are Bluetooth sensors that can interact with a device (e.g., iPhone, iPad, and Google Glass) by delivering different information according to the distance of the device from the sensor [Newman 2014]. I was invited to this experiment as a participant. During the test, when I approached a particular object on display – in which was placed the iBeacon transmitter – the sensor detected my location and sent relevant information – usually in the form of video – to the Google Glass I was wearing. Everything happened automatically without the need to trigger any command. Also the de Young Museum in San Francisco, in 2014, developed a project that adopts an interpretative strategy, offering the visitor a contextual information experience based on the integration of Google Glass and iBeacon.[5]

The experiment I present in this article it is a contribution to the body of research into this new type of interpretative digital media in the cultural heritage sector. The lack of studies on the new generation of smart devices such as Google Glass suggests undertaking an exploratory research approach in order to understand more about it. The main purpose is to contribute the groundwork that will lead to future projects; and, at the same time, to create links to extant literature in the field. For this reason, the intent of the experiment was to provoke thought, and consisted of using the MIT Museum Glassware prototypes to produce reactions in the visitor. The main objective was not to gather information to specifically refine the usability of the MIT Museum Glassware prototype created for the experiment; instead, it was an occasion to explore visitor experiences in order to collect experiential perspectives useful for informing future designs of glasses as interpretative devices.

3. RESEARCH METHODOLOGY

To explore the use of smart glasses in the museum setting, we designed and implemented a functional Glassware prototype and tested it through field experiments, during which twelve visitors interacted with the prototype. The context of the field experiments was the Robotics Gallery at the MIT Museum,

[3] https://www.youtube.com/watch?v=NVdquY-XF9s.

[4] The IWM teamed up with a company based in France – Guidigo, an approved app provider for Google Glass https://www.guidigo.com/ – to make a tour of the First World War Galleries at IWM London with Google Glass.

[5] "GuidiGO new storytelling platform enhances Keith Haring exhibition at the de Young Museum through Google Glass": http://blog.guidigo.com/blog/guidigo-new-storytelling-platform-enhances-keith-haring-exhibition-at-the-de-young-museum-through-google-glass.

Fig. 2. The Robotics Gallery at the MIT Museum. Credit: The author is grateful to the MIT Museum.

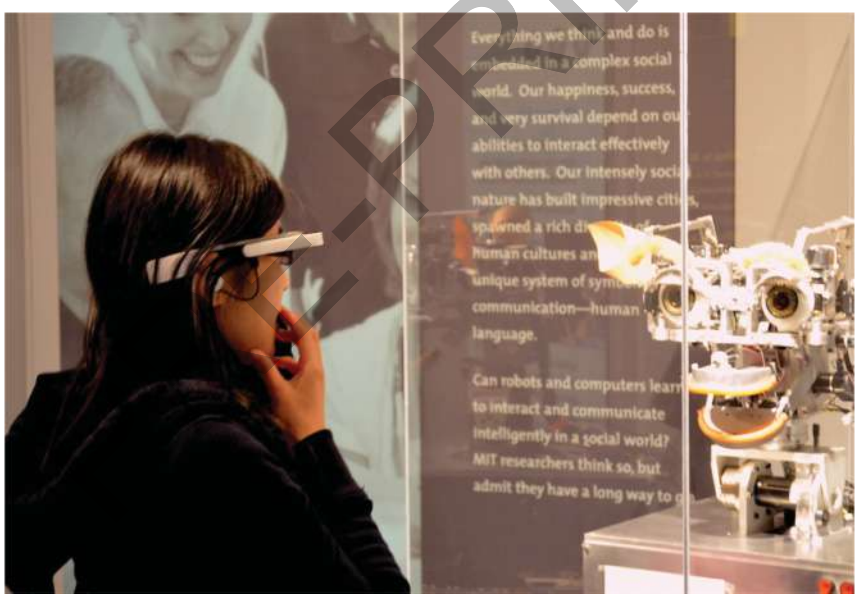


Fig. 3. A participant during the experiment session. Credit: The author is grateful to the MIT Museum.

which is a permanent exhibition about Artificial Intelligence research at MIT (Figure 2). I also conducted participant observations during each experiment (Figure 3). Then, I analysed the qualitative data gathered through open interviews.

The data gathered through the interviews were analysed through thematic coding, following a qualitative research methodology [Richards 2009]. Adams et al. [2008] explain how a qualitative approach can "deliver the research results that Human Computer Interaction needs": for example, to better design new technology based on user needs instead of functionality alone. According to the authors, "with qualitative research, the emphasis is not on measuring and producing numbers but instead on understanding the qualities of a particular technology and how people use it [. . .], how they think about it and how they feel about it" [Adams et al. 2008]. For this reason, this article does not provide quantitative information. The discussion that follows in this article presents findings emerging from the qualitative research carried out with the aim of bringing insights and reflections to inform the design of smart-glass-enhanced visitor experience.

3.1 Procedure

In a partnership sponsored by the Undergraduate Research Opportunities Program[6] at MIT, I collaborated with an MIT undergraduate student and the MIT Museum Studio to conduct an exploration of the Glassware prototype.[7] The Glassware was implemented using the Glass Development Kit – GDK [Google 2015a] an add-on to the Android SDK that allows the building of apps (namely, Glasswares) that run directly on the Google Glass.[8]

The team was constituted by an MIT student (computer scientist) who worked in close collaboration with myself (digital media designer) and the director of the technology at the MIT Museum; and two MIT Museum curators who offered support and provided the content for the Glassware. In the conceptual phase the underlying concept of the information structure of the Glassware emerged, which is articulated in four sections (see below). In developing this concept, we considered the MIT Museum audience and their needs (consulting both the recent MIT Museum "Five-year strategic plan" and the suggestions coming from the experience of the director of the technology and the two curators, gained in more than ten-years of work at the MIT Museum). We were also guided by the type of visitor's behavior that Raptis et al. [2005], referring back to Levasseur and Veron [1989], described through four metaphors, based on path and movement: *fish* ("visitors who move most of the times in the centre of the room without looking at exhibit's details"), *ant* ("visitors who follow a specific path and spend a lot of time observing almost all the exhibits"), *butterfly* ("visitors, who don't follow a specific path, are guided by the physical orientation of the exhibits and stop frequently examining their details"), and *grasshopper* ("visitors whose visit contains specific pre-selected exhibits, and spend a lot of time observing them"). These visitor characteristics were considered during the conceptual phase and, in certain ways, influenced the four guide sections described below. This was in order to cover, with our prototype, different kind of visitor attitudes, and thus be of benefit of the exploration and the resulting findings. The information structure of the MIT Museum Glassware prototype is constituted in four sections: Overview, On Display, QR code, and Start a Tour (Figure 4). In any section, the visitor can access different types of interpretative content and, therefore, try out different kinds of experiences (Figure 5).

The "Overview" consisted of a one-minute video in which the curator introduces the four sections into which the Robotics Gallery is organized: Socializing, Moving, Sensing, and Learning. The "On Display" section had a more articulated information architecture, consisting of two layers of information. The former presented the pictures and names of the three robots involved in the experiment. The latter showed more specific information associated with each of the three robots. We used several media to present different kind of contents – from video and pictures to text and audio. The "QR code" function

[6]http://web.mit.edu/urop.

[7]The design team with which I collaborated was constituted of: Prof. John Durant – Science, Technology, and Society Program at the Massachusetts Institute of Technology and director of the MIT Museum; Allan Doyle – Director of Technology at the MIT Museum and Co-director of the MIT Museum Studio; and Chun Kit Chan – exchange student in Electrical Engineering and Computer Science Department at the Massachusetts Institute of Technology.

[8]Readers can find further information about technical future in Muensterer et al. [2014] and Rhodes and Allen [2014].

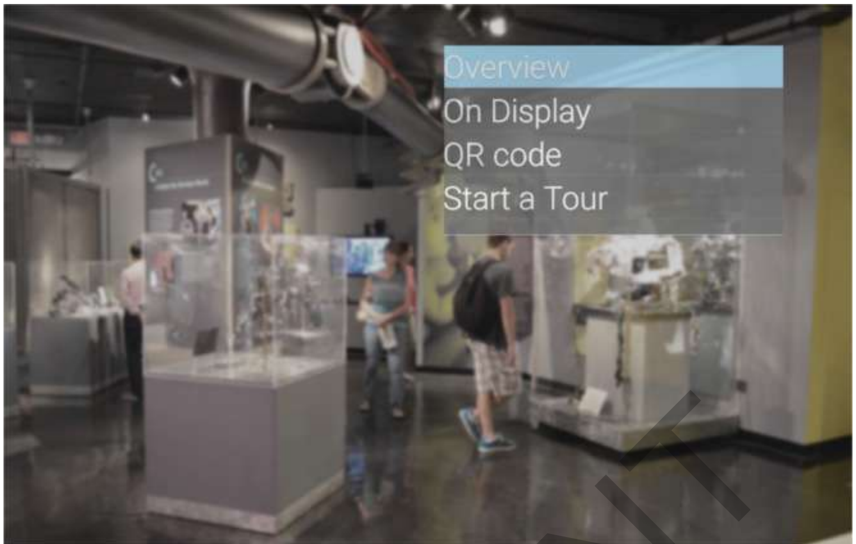


Fig. 4. The opening card (home page) of the MIT Museum Glassware prototype. The visitor can scroll up and down to select one of the four sections: Overview, On Display, QR code, and Start a Tour. Credit: The author is grateful to the MIT Museum.

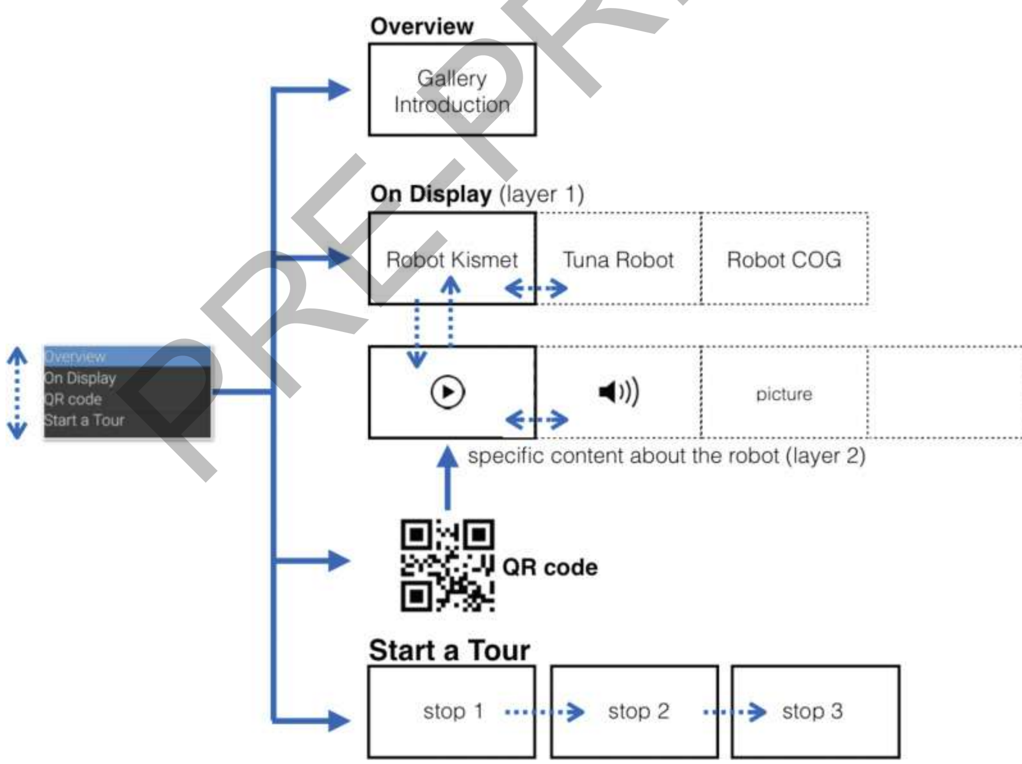


Fig. 5. The MIT Glassware interface map (in "blue" are indicate the gestures, see also Figure 6). Credit: Marco Mason.

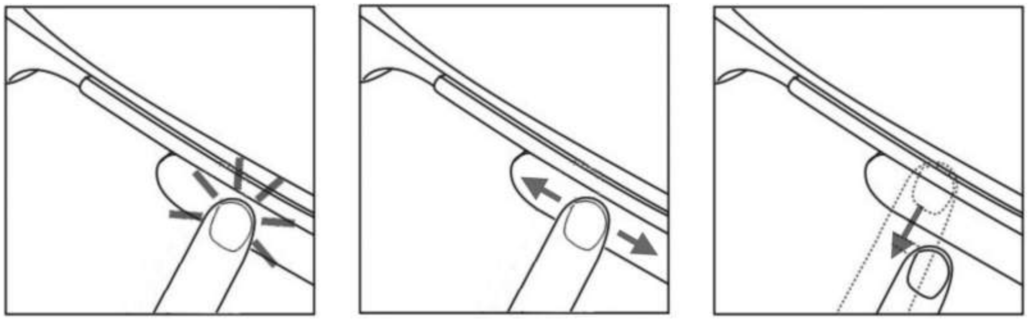


Fig. 6. Google Glass gestures: (from the left) "Tap", "Swipe forward and back", and "Swipe down." Credit: Source of original images: https://support.google.com/glass/answer/3064184?hl=en.

Fig. 7. The MIT Glassware, photo editing (credit: Marco Mason). Credit: The author is grateful to the MIT Museum.

was implemented with a Quick Reading scanning function. Finally, the "Start a Tour" section presented a short tour, which used floor plan maps to indicate the positions of the three robots in the gallery. An audio voice guided the visitor to move from one robot to another, inviting them to discover where the next robot was located. The users used the standard Google Glass gestures – "Tap", "Swipe forward and back", and "Back" – to move within the interface (Figures 6(a), (b), (c)).

The MIT Museum Glassware was designed and developed using principles provided by the "Google Developers" website [Google 2015b], which offers "best practice" advice about design principles, user interfaces, navigation patterns, and design style; beyond that, it provides information for developers. As we saw above, the first card[9] that appeared to the participants when they opened the MIT Museum Glassware, consisted of the home page (Figure 5) on which they could choose among four sections by "Swiping forward and back" (Figure 6(b)) and "Tapping" the touchpad (Figure 6(a)). For example, if the visitors selected the "On Display" section another "layer" of information would be opened (Figure 7). At this point, the visitors could select, by "Swiping forward and back", from Kismet robot, Tuna robot, and Cog robot. If the visitor decided to receive more information about, for instance, Kismet, then they

[9] In a Glassware, each page is called "card."

Table I. Participants

Participants	Gender	Age	Education	Tech-savvy
P1	Female	30-39	Postgraduate	Medium
P2	Female	20-29	Undergraduate	Low/Medium
P3	Male	20-29	Postgraduate	Medium
P4	Female	20-29	Undergraduate	Medium
P5	Male	20-29	Postgraduate	Medium
P6	Male	20-29	Postgraduate	High
P7	Female	20-29	Undergraduate	Medium
P8	Male	20-29	Undergraduate	Medium
P9	Female	20-29	Undergraduate	Medium
P10	Male	40-49	PhD	High
P11	Female	40-49	PhD	Medium/High
P12	Male	30-39	PhD	High

Profile "Medium", Approximate characteristics: Average skills in the use of operative systems and software; Sometimes, advanced skill in specific software (e.g., CAD or photo editing); Basic/general knowledge of hardware components; Ability in the mobile apps; General interest in cutting-edge technology (e.g., reading news from magazines); no skill in software coding. Profile "high", approximate characteristics: Advanced skills in the use operative systems and software; Advanced knowledge of hardware components; Ability in using mobile apps and cutting-edge technology; High interest in cutting-edge technology; Medium/advanced skills in software coding

had just to "Tap" on the Kismet robot card. At this point, a deeper level of information was displayed. Now, by applying the same interactions, the visitors could "Swipe forward and back" to explore specific content, which was presented in form of video(s), text(s), or still image(s). Finally, they could "Swipe down" (Figure 6(c)) to move back to the previous level or even to the Home Page, as this gesture acted as a back button.

3.2 Participants

For this study, I recruited twelve participants (Table I). They were all residents in the Great Boston Area, Massachusetts. The participants were MA students (5), doctoral candidates (3), and researchers (2) at the institutions present in the area. Two of them were professionals working, respectively, for a software company and design firm. None of them were involved in digital media for cultural heritage. They were originally from different countries in America, Europe, and Asia. Their ages were between 20 and 49 years old. This audience is representative of a significant portion of people studying and working in Boston and Cambridge (where MIT and Harvard are located). Thus, they also reflect a segment of the MIT Museum audience. The participants were quite accustomed in using digital gadgets and, in three cases, they would also provide educated insights into design issues (as their backgrounds were in electronic engineering and design).

3.3 Data Collection and Analysis

Each exploration with the visitors lasted between 30 and 40 minutes, and was followed by another 40 minutes of interview.[10] Since none of the participants had used Google Glass before, it was necessary to train each participant in getting used to the Google Glass gestures and navigation. This introduction

[10]Many of the respondents were not native English speakers, and that, whilst it has no bearing on my project here, is worth noting when reading the extracts of the interviews.

Fig. 8. The smartphone on the left recorded the visitor using the Glassware. That on the right, showed, in real time, the interface the visitor saw in the Glassware functional prototype. Credit: The author is grateful to the MIT Museum.

lasted between five and ten minutes. The training never asked the participants to use the MIT Museum Glassware. Instead, I showed them an interface map (similar to those in Figure 5) to give them an idea of the information system. This was to limit any influence on the visitor experience.

I did not assign participants any strict task in order to leave them sufficient freedom to use the Glassware as they preferred. However, I asked them to follow some instructions: (1) To start with the "Overview" section; (2) To start and conclude the sections they selected before moving to another one, avoiding jumping around the Glassware interface haphazardly (for example, because they were only curious to try the Google Glass technical features). I did not impose any time limit.

I observed visitors using the MIT Museum Glassware prototype in the gallery. I was also able to see what was displayed in the Google Glass thanks to a mobile screen I was carrying with me during the observation (Figure 8). In this way, I could observe not only the movements and interactions of the visitors within the gallery and with the objects on display, but also the interactions they were conducting with the Glassware interface. The observations were videotaped (except in three cases) and pictures were taken for both coupling this data with interviews and documenting the experiment. All interviews were conducted at the MIT Museum after each exploration. Most of the time the interviews took place in the Robotics Gallery in order to be "in the field" after the conclusion of the experiment itself. The interview sessions were audio recorded and transcribed. When this was not possible (e.g., because the participant did not give consent or for a technical problem) extensive notes were taken.

The interviews were based on a qualitative research protocol that allowed participants to describe which things were meaningful and significant for them [Kvale 2008]. I adopted an in-depth interview approach. In particular, I choose an "Interview Guide" format [Patton 1990], which was based on a common outline of issues related to the visit experience facilitated by the MIT Museum Glassware prototype. I used a qualitative interview structure [Rubin et al. 2005; Turner III 2010] as it provides a method for collecting rich information about how the participants experience the visit with the

Glassware prototype. The exploratory character of my study and the relatively little previous research on Google Glass made it difficult to test specific tasks and interactions. Therefore, because the aim of the study was highly exploratory, I chose an interview approach that did not use a fixed questionnaire, in which all participants were asked the exact same set of questions. Thus, the interview structure was very flexible and not restricted to predetermined questions, making it possible to adapt the way I posed questions according to participants' responses. I consider this approach most appropriate for an early stage exploration because it allowed interviewees to respond according what their thoughts were and not to specific and detailed questions, providing the broadest set of perspectives. In order to give the participants some general directions and, at the same time, to stimulate the conversation on their individual experience, I structured the interview around the four main areas related to the four sections of the Glassware that help me to establish the main topics of the discussion. I asked about their experience ("Can you tell me about your experience with the introductory video?"). Then, follow-up questions were used to stimulate expansion of thoughts ("Can you tell me more about your experience with the introductory video?"; "What do you mean by the expression 'more personal' "?, etc.)

The information, experience, and viewpoints gathered from participants were then analyzed and interpreted. I used a piece of Computer Assisted Qualitative Data Analysis Software[11] (CAQDAS) named NVivo [Bazeley and Jackson 2013], which supported the work of managing and analyzing the data. I started the analysis using an "open coding" approach that consisted of reading through the transcriptions and interview notes in order to break down data into significant segments, which I then labeled. The labels consisted of a few words that briefly described the essential property of the segment. During this process of labeling, patterns of similar properties started emerging. At the same time, I constantly wrote memos each time significant reflections emerged from the analysis. The memo process helped in the abstracting themes from the data [Birks et al. 2008]. Through constant reflection and comparison, and refinement of these patterns, six themes were identified. The six emerging themes are presented and discussed in this article and extracts from the interviews illustrate each theme: (1) Looking at the object on display; (2) Digital content for smart glass applications; (3) Constant availability of information according to head orientation and location; (4) Direct access to the content; (5) Navigation throughout the gallery; and (6) Sharing the subjective point-of-view experiences.

Q7

4. FINDINGS

4.1 Looking at the Object on Display

The Google Glass is an optical see-through head-mounted display,[12] which allows the visitor to see through it, favoring visual contact with the object on display while receiving information through the device [Muensterer et al. 2014]. The participants appreciated this capacity. For example, I asked questions about the short videos displayed on the MIT Museum Glassware that presented the facial expressions of the Kismet robot (Figure 9). These 4- to 5-second videos showed how the robot reacted to the voice of a person "speaking" with it in order to engage people in natural and expressive face-to-face interaction.[13] The same content was also made available on the monitor alongside the display where the Kismet robot was located. In the following extracts, participants compared the two ways in which the content was provided (the Glassware and the monitor). They confirmed the strength of the smart glass experience, expressing preference for watching them with the Google Glasses instead of the monitor. Aspects that were enjoyed by the visitors included:

[11] http://en.wikipedia.org/wiki/Computer-assisted_qualitative_data_analysis_software.
[12] http://en.wikipedia.org/wiki/Optical_head-mounted_display.
[13] http://www.ai.mit.edu/projects/humanoid-robotics-group/kismet/kismet.html.

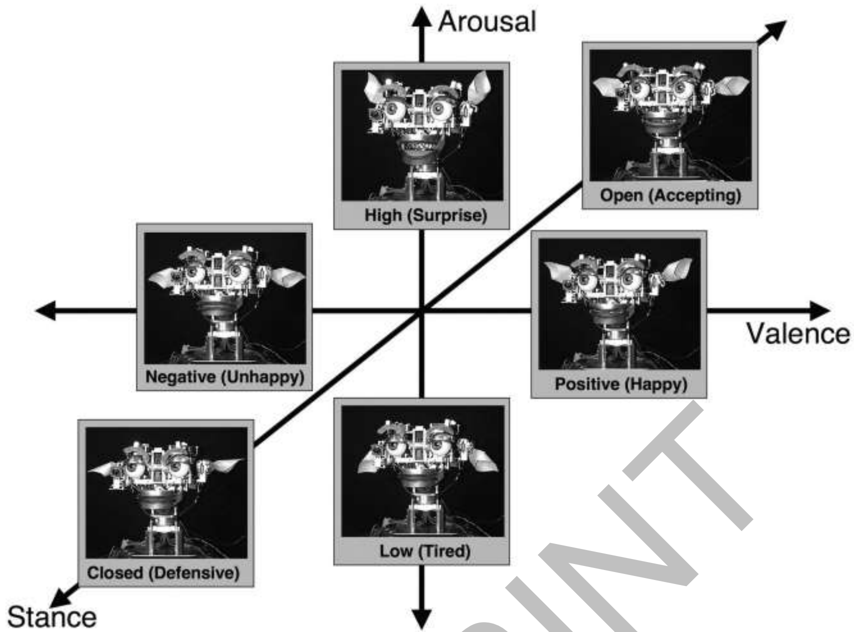


Fig. 9. Kismet robot facial expressions. Credit: C. Breazeal. 1999. Robot in society: friend or appliance. In *Proceedings of the 1999 Autonomous Agents Workshop on Emotion-Based Agent Architectures* (Figure 7).

P1: "*Information is right in between your eye and the object on display. You do not have to switch your attention to watch the video on the mobile.*"

P4: "*The contact with the Kismet robot is more direct. I would say more personal.*"

It is interesting to note the preference expressed by the participants for the experience offered through the Google Glass, as emerged from the following quote:

P6: *"With the Glass it is possible to watch the video and at the same time see what is in front of me. I can constantly compare these two pieces of information. It gives me more real experience because it is much easier for me to see the video and the object in front of me. I don't have the necessity to look at other screens."*

One of the underlying aspects that characterizes smart glasses (and differentiates them from a smart phone) to consider when designing for smart glasses in museum contexts is the "balancing act" that visitors have to make for assessing the attraction of a particular stimulation and switching their attention to the stimuli they consider more attractive [Woodruff et al. 2001].

4.2 Digital Content for Smart Glass Applications

Another aspect that emerged from the experiment is related to the type of content provided through the MIT Museum Glassware. In the MIT Glassware prototype, we used different types of media – text, audio, static images, and videos – according to the interpretative information we wanted to transmit.

From the qualitative interviews, it emerged that all participants found the content clear and useful as complementary information to better understand the objects on display. For example, a visitor found the video meaningful as it offered her the possibility to better understand the object in movement (e.g., Kismet facial expressions). Even if this study did not specifically aim to evaluate the glassware's

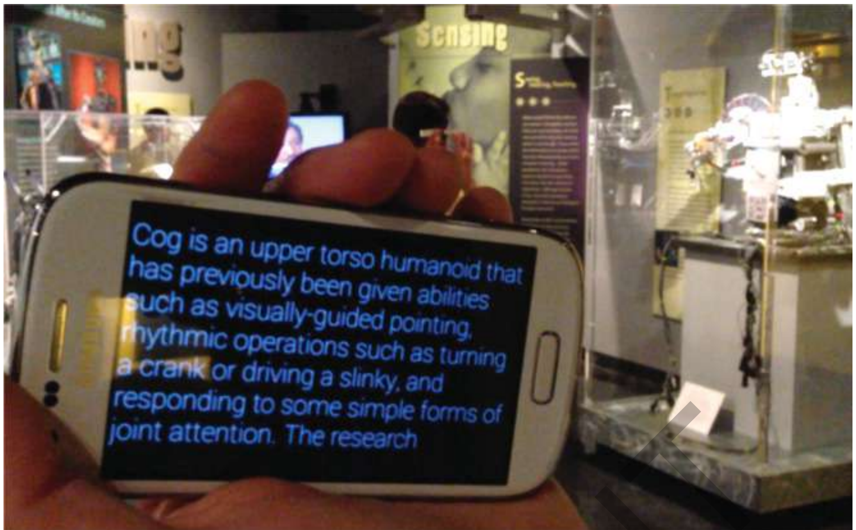


Fig. 10. The picture shows the text displayed on the Google Glass while a participant was looking at Cog robot. The description was divided in two cards as it was "too long" for one screen only (the participant used the "Swipe" gesture to move from screen to screen – see Figure 6). Credit: The author is grateful to the MIT Museum.

usability, two issues surfaced: the difficulty to read (long) texts and the excessive length of some videos. The text we used to describe some robots was around 70 words in length (Figure 10). The participants did not express particular enthusiasm for this form of content because it was too long and not always easy to read. Instead, they appreciated it when similar form of written/textual were presented in audio thanks to a text-to-audio translation function the Glassware for Google Glass offers, which allows the device to read the text displayed in the optical and then convey it to the visitor in the form of an audio track.

Concerning video, we noted that the content provided by Google Glass should not be as long as that usually created for a mobile app. In the MIT Museum Glassware, we used a 1-minute-and-10-second video to describe the robot Tuna. Even if the visitors reported that the duration was acceptable, I observed that most of them began looking at other things and stopped watching the video after 10 to 20 seconds, starting to look at the robot on display, and losing the focus on the video. When I asked more specific questions regarding this point, some visitors reported that they stopped watching the video and just listened to the audio commentary while looking at the object on display:

P7: *"[. . .] With the Google Glass you cannot stay focused for long time, since after a few seconds you are distracted. [Instead] with a traditional [interpretative] label you are totally immersed and do not have any distraction."*

This exploration suggests a multi-content experience and, at the same time, it warns of the risk of using media such as text and (long) videos because they are not necessarily the most effective when conveyed by very small screens in optical see-through head-mounted displays. For example, we used a combination of static images and videos to show how the Cog robot approximates the sensory and motor dynamics of a human body. According to the MIT researchers[14] who worked on the Cog project "the head, torso, and arms of the Cog robot together contain twenty-two degrees of freedom. They allowed

[14] http://www.ai.mit.edu/projects/humanoid-robotics-group/cog/overview.html.

Cog to accomplish very complex actions such as 'playing' with a spring." The "degrees of freedom" were particularly intriguing for the visitors. However, from the interviews, it emerged that still images are just one possible, probably limited, way to convey this kind of content. According to many participants, a smart glass should offer the possibility of more advanced media. During several interviews, visitors expressed the desire to see a different kind of overlaid information (rather than a simple image or a video) to understand the Cog robot's degrees of movement:

P10: *"Actually, devices like the Google Glass could work better than just displays of kind of static content. My guess is that the Glass could be useful for more dynamic kinds of information and interactions – and I'm not only thinking of images or videos – between people and objects."*

P8: *"It would be awesome to use "explosion" of the elements to see how each part [of the robot] works. Or, for example, some physics of the forces implied in the movement of the arms of the Cog robot. Besides, for example, it would be great if I could kind of "choose" one part of the robot, the arm for example, and get "physics" information about that part. For example, how it moves, which directions have the forces implied. Something like that."*

These extracts suggest the adoption of more dynamic and interactive ways of presenting information. Possible scenarios include the adoption of animations or a sequence of dynamic images that allows visitors to explore the objects on display through an overlapping of images and diagrams on the object she is looking at.

4.3 Constant Availability of Information According to Head Orientation and Location

The visit started with an introduction ("Overview" section of the MIT Museum Glassware) that presented the Robotic Gallery to the participants. In this introductory video, the curator describes the four sections in which the Robotics Gallery is organized: Socializing, Moving, Sensing, and Learning.[15] The participants expressed the benefit of having introductory content provided through a portable device. In the following interview extract, a visitor confirmed the advantage, also for the introductory content, of receiving information provided through an optical see-through head-mounted display:

P2: *"The introduction is similar to an introductory label at the entrance of the gallery. But I prefer the Google Glass because you can walk around and enjoy the introduction. The introductory video shows some parts [the four by which the gallery is articulated]. I walked around the gallery to see each part."*

Interviewer: *"But you could have this kind of information also on a normal mobile phone, without the necessity of buying an expensive smart glass."*

P2: *"Yes, but what is better with the Google Glass [compared to a smartphone] is that you can walk without looking at the iPhone display. Information is easily available just right on your eye."*

However, five visitors reported some difficulties in following what the curator was describing in the video and looking around the gallery at the same time. The problem was not due to a lack of content or poor-quality narration (on a smartphone, the same video works pretty well, providing a helpful overview of the gallery and a meaningful experience for the visitors), but to a mismatch of information, which turned out to be confusing for the visitor. Therefore, I triangulated the interview data with the videos recorded during the observations noting that often happened that the visitors were looking at a specific section of the physical gallery (e.g., *Sensing*) and, at that moment, the video was showing another section (e.g., *Socializing*), provoking a mismatch of information between what the visitor saw

[15]The author is grateful to Dr. Deborah Douglas (MIT Museum curator) and Kurt Hasselbalch (MIT Museum Hart Nautical Collections) for the digital content they provided.

Fig. 11. A participant in the experiment is using the QR Code function implemented in the MIT Museum Glassware prototype. Credit: The author is grateful to the MIT Museum.

in the physical space and what the smart glass displayed. In this case, the lack of functionality that could allow the content to change according to what the visitor is looking has decreased the quality of the visitor experience.

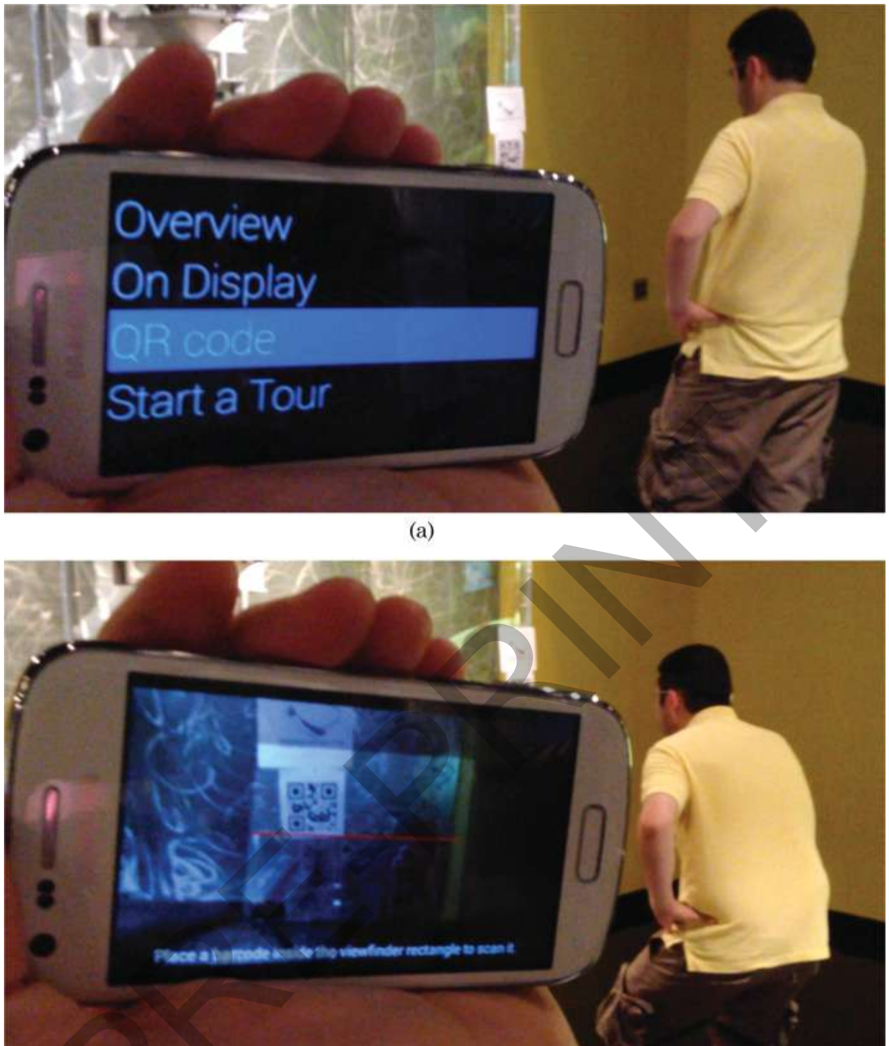
4.4 Direct Access to the Content

The Glassware was implemented with a function that allowed visitors to directly receive information about the object once they got close to it, instead of browsing through the Glassware interface to find the content related to that particular object on display. The Quick Response (QR) function implemented in the MIT Museum Glassware was particularly appreciated, since it allowed visitors to quickly receive information related to the object on display they were interested in at that moment. We placed QR codes alongside the robot displays (Figure 11). When the visitor was walking around the gallery, and a particular robot caught their attention, they got close the display and scanned the code by tapping the Google Glass when looking in the direction of the QR code. Information immediately appeared on the Google Glass display (Figures 12(a) and 12(b)).

P9: "*I do not read or look at info before starting the visit. I just walk and stop whenever I am interested in something. For example, with the QR code, if you are interested in a particular robot, you get close to the object and scan the [QR] code to know more, otherwise you can keep going.*"

Although it was the first time the participants used QR code with the Google Glass, they reported a positive experience, because of the ease of obtaining information:

P1: "*The [Tuna] robot got my curiosity; I got close to the case [where the robot is displayed]; I just looked at the [QR] code and tapped the Glass: tac! [Voila!] I immediately got the information without having the necessity of moving around the Glass interface to find it.*"



(a)

(b)

Fig. 12. The picture shows a participant using the QR code function. Credit: The author is grateful to the MIT Museum.

The main advantage of using QR codes with the Google Glass is that of reducing the effort and time required to get the information. The visitor does not need to open (and maybe previously download) the QR scan app, handle the mobile device, then point it toward the QR code, and finally scan it. Everything is essentially reduced to a "tap" (click) on the Google Glass to open the "QR core" function that scans the QR code located on the exhibit.

4.5 Navigation throughout the Gallery

The experiment confirmed that navigation is a critical design issue for a meaningful visitor experience, not only with mobile devices but also with smart glasses. The MIT Museum Glassware experiment did not use any indoor navigation system for this experiment since, even if there are more and more

Fig. 13. The map used to indicate the position of the robots in the gallery. Credit: The author is grateful to the MIT Museum.

researchers working to find an effective solution to this issue [Kim and Jun 2008; Fallah et al. 2013; Kasprzak et al. 2013; Xu et al. 2014; Yang et al. 2015; Bettadapura et al. 2015], the technology commercially available is still lacking; and it was not the aim of the experiment to create new technology.

Therefore, for the MIT Museum Glassware prototype, we created a short tour using a floor plan map. On the map, we located the position of the robots in the gallery (Figure 14). Then, an audio recording guided the visitor to move from one robot to another,[16] inviting them to discover where the next robot was located. The aim of this short tour was to stimulate conversation during the open interviews in order to foster visitor reflection. The interviews raised two main interrelated issues concerning Google Glass navigation systems. First, it was discovered that it is crucial to provide the Glassware with a pinpoint accuracy function, in order to better locate the visitor's position within the gallery. For example, with a traditional floor map displayed on a mobile phone, the users can recognize the place that surrounds them without any huge difficulty – and therefore easily recognize their position within that space – by turning the map (and the display) around to the orientation that better corresponds with the physical environment. In other words, it is easy to benchmark physical space against the map on the display. However, it is more difficult to achieve the same result with the Google Glass. Because our map did not rotate automatically according to the direction the visitor was looking and, moreover, did not intuitively note obvious landmarks, allowing the visitor to move in the right direction, usability suffered. This suggests that the visualization of a static floor plan map in an optical see-through head-mounted display seems not to offer the best visitor experience. The second issue is a consequence of the former. From the open-structure interviews emerged a widespread desire to have at their disposal some kind of navigation system involving dynamic signals – which could eventually appear on the map – jointly with a guiding voice. According to what visitors described, this system – constituted of signal

[16]The instructional text to reach the first robot of the tour: "Hello! I am Kismet and I am a robot with a really pretty face! I have shiny blue eyes and beautiful red lips! Find me in the gallery! Once you find me and you are right in front of me, please, tap the Glass to get more information!"

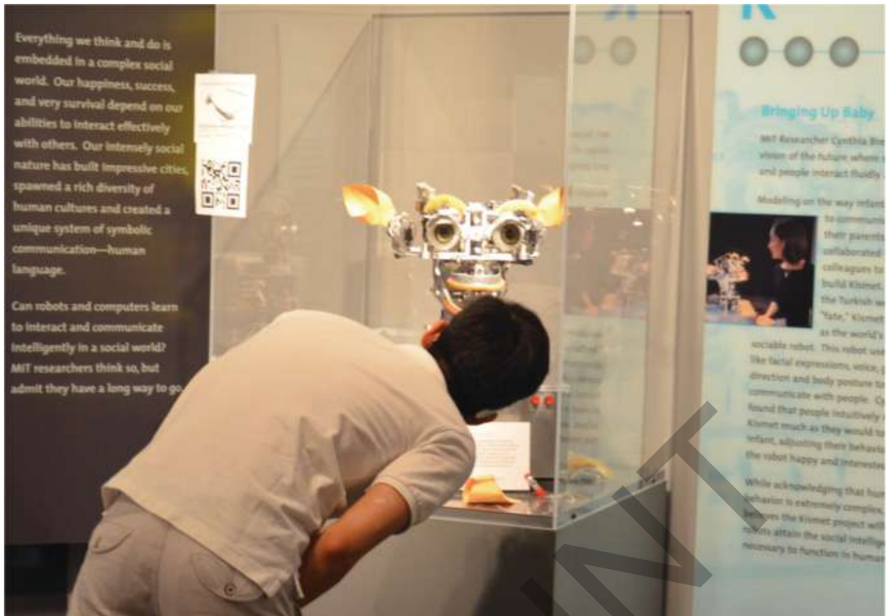


Fig. 14. A participant is observing the Kismet robot during a MIT Museum Glassware experiment session. Credit: The author is grateful to the MIT Museum.

and voice – should work as a personal navigation system conducting them throughout the gallery to the objects on display.

4.6 Sharing the Subjective Point of View Experiences

For the MIT Museum Glassware prototype, we did not implement any sharing features. However, I raise this issue in this article because I think it significant. In fact, from the first open interview, the question of sharing content or experiences through social networks was a topic of discussion. For this reason, starting from the second participant, at the end of the interview, I asked questions related to why they thought a smart-glass-enhanced experience should offer (new) engaging ways of sharing information outside the museum walls, and if they might envision possible scenarios. Participants expressed the desire to share information with friends or parents, especially the participants who had friends and parents outside of the USA. The following extract seems particularly meaningful:

P3: "*What a smart glass could do different from my smartphone? For me? Well, it could be the possibility to share the entire video I have just watched. Or, even better, something I have recorded. I mean, take that moment! I can take it quicker because the [smart] Glass is handy and you wear it. [...] It is because of the different angle. It is 100% my experience, right in that moment.*"

With this issue in my mind, I then started observing the behaviors of the participants considering how the Google Glass might foster new ways of using social networks. In several evaluation sessions, I noted that participants often assumed particular postures to see the robots from a particular point of view ("It is because of the different angle"), for example, the underlying mechanism of the Kismet's mandible system or the arm joint system in Cog robot, which seemed to be characteristics that attracted the curiosity of the participants. Figure 15 well illustrates this kind of visitor behavior. It appeared a clear wish of participants to share that kind of experience ("it is 100% my experience, right in that moment") with others through social networks ("it could be the possibility to share [. . .] something I have recorded").

It seems that one of the novelties that wearable glass brings is the "subjective point of view." This is evident if we think of the current and most widespread use of the Google Glass, and wearable smart glasses in general – that it is mainly used to shoot, share, and broadcast a huge amount of pictures and videos all from a recognizable personal perspective. This has become a distinguishing feature of the Google Glass that museums can offer to their visitors.

5. DISCUSSION

From my study, it shows that a smart glass facilitates visual contact with the object on display while visitors receive information from the optical display, as they literally wear the device. The use of a Google Glass to access information facilitated the participant's "balancing act" by offering a more immersive experience as they did not have to look away from the robots on display or "look back and forth" between the object and monitors aside the exhibit or handled by the visitors [Novak et al. 2012].

Previous research conducted in museum settings [Hall et al. 2001; Sparacino 2002; Novak et al. 2012] describes the different advantages of providing information through optical see-through head-mounted displays, instead of via a smartphone. For example, according to Sparacino [2002] "one of the main drawbacks of [mobile] devices is that the visitor is obliged to toggle his/her attention between the objects on display and the handheld's screen, alternately looking frontally towards the objects and then down to the screen." According to Woodruff et al. [2001], visitors perform a "balancing act" anytime they have to assess the attraction of a particular stimulation and switch their attention to the stimuli they consider more attractive. Depending on what they consider more attractive, visitors respond differently to the changing stimuli coming from different entities: this contributes to create a fulfilling experience. In other words, the cognitive act of looking through an optical see-through head-mounted display offers a more immersive experience (compared to mobile devices) since visitors can stay more aware of their context when receiving information [Kiyokawa 2008; Klopfer 2008].

The participants reported some difficulties reading the text on the Google Glass display. The length of the text (around 70 words) would have not been "long" if read on a smartphone display. One reason could be related to the user's attention focus, which is shorter in very small displays. There is also a need to consider that participants, who had never tried the Google Glass before, were not familiar with this "new" way of displaying content; and the "feeling of familiarity" is an aspect which needs to be considered when investigating the display of information [Cameron et al. 2015]. Even if it was not the aim of this exploration to evaluate reading tasks (and further specific usability studies are required), it emerged pretty clearly that it is important to create forms of digital content that fulfill the particular form factor of the optical see-through head-mounted displays, while satisfying the interpretative goals. The next generation of smart glasses applications for museums should adopt specific strategies to tailor their content for this particular type of interpretive device. Beyond tailoring existing types of content successfully used on mobile apps in museum settings such as video, images, and audio [Mason 2012], the smart glasses should consider implementing innovative and dynamic forms of content.

Augmented Reality (AR) research shows promising advancement in the field of digital heritage for innovative wearable interpretative strategies to enhance visitor experience [Damala 2013]. A new vein of research on AR applied with smart glasses can rely on a formed body of knowledge on AR for mobile devices that has been implemented over more than 10 years of research [Damala 2013]. For example, ARtSENSE was a interesting research project that studied AR see-through glasses in a museum context by creating a prototype that combined visual, audio, and physiological sensors to create a personalized experience where visitors could receive tailored content [Damala et al. 2012]. The project introduced the concept of Adaptive Augmented Reality (A2R) to "augment" the museum visit in highly personalized way [Damala 2013]. According to the project summary[17] presented in the European Commission CORDIS FP7:

> *"ARtSENSE aims to develop active assistants which look over the user's shoulder (physical world) and react on any change in a visitor's state of interests (user's world) by adapting the "guide" (digital world) accordingly. [...] ARtSENSE will revolutionize the way how adaptive assistance will be realized: using cutting-edge technology (low-weight bidirectional see-through displays) that enables overlaying reality with digital information transparently, including gaze- and gesture-controlled interaction, so that visitors have the feeling that physical objects are directly responding to them [...]"* [ARtSENSE 2012]

This promising scenario envisions how smart-glass devices could implement gesture controls by integrating gesture recognition functionality into Glassware for the Google Glass, such as the one that a pioneer company[18] in the field is developing (for now in beta), which allows the device to "recognize" the gesture of your hand in order to provide commands to the Glass, instead of "tapping" or "talking with" the device. This possibility could open interesting opportunities for interactive learning and visitor engagement in museums. For instance, content provided through head-mounted displays could become interactive and "manipulable" and visitors wearing the smart glasses might dynamically interact with information overlaid on the object on display. For example, the different components constituting Cog robots could become, through the content provided in AR, interactive and "manipulable", and visitors wearing the smart glasses might dynamically interact with information overlaid on the object on display: for instance the visitor might select one component (e.g., a 3D model of the robotic arm) and explore its characteristics in more detail by zooming or rotating the model[19]. This futuristic scenario is an object of research also in industry such as, for example, functional prototypes that use AR and smart glasses to map virtual objects into the physical world, controlled by the users' hands [CNet 2013; META 2015].

We have seen above the advantage of wearing Google Glass to facilitate the visitor's "balancing act": the participant can look frontally towards the robot on display without the need to switch their gaze to the smartphone in their hand. What could be an asset may be, in particular circumstances, a detriment if the content is not properly delivered considering the position of the device display right in front of the users' eyes, as happened in the case of the Robotic Gallery introductory video, where participants experienced a mismatch of information.

The wearable glass technology does not only support innovative ways of conveying content but also implements increasingly sophisticated visual and head orientation sensors that allow the determination of the direction of interest of the visitor [Damala and Stojanovic 2012; Kiyokawa 2012], thus offering a more immersive and personalized experience by providing information according to visitor head orientation and location. Such possibilities could have enhanced the participants' experience when watching the introductory description of the Robotic Gallery, avoiding the mismatch of information thanks to a more direct correspondence of the content with what the visitor was looking at that moment in a specific position in the gallery.

[17] http://cordis.europa.eu/project/rcn/97475_en.html (ARtSENSE was indeed a promising project which was cancelled).

[18] The pioneer company is a Portland, Oregon startup called On the Go Platforms. Read more: http://www.digitaltrends.com/features/google-glass-meets-kinect-ari-gesture-recognition-app-smartglasses/#ixzz3OiGAh2y7; http://www.engadget.com/2014/01/08/onthego-platforms-google-glass-gesture-recognition-controls/.

[19] I suggest watching this video that envisages possible future ways of interacting with digital content in AR within the physical world: https://www.youtube.com/watch?v=b7I7JuQXttw.

Defining the notion of context and its constituent dimensions (system, infrastructure, domain and physical context), Raptis et al. [2005] underline the important of infrastructure, and domain and physical context respectively for convening timely information and design interactions between visitor and the system in the best way while considering the relation of the system with the physical environment. This will lead to the development of smart glass apps that will take full advantage of technological capacity of identifying the position and the direction of sight, promoting new forms of interaction. For example, in the "egocentric interaction" model described by Pederson et al. [2010] a new framing of interaction is emerging, where the "human body and mind of a specific human individual that (literally) acts as center of reference to which all modelling is anchored in this paradigm." A significant aspect of this model is the promotion of a kind of interaction that considers first-person's head orientation information (e.g., what the user is looking at) as one of the central factors to exploit when designing for wearable glass information systems [Battadapura et al. 2015].

Smart glass apps could offer visitors a more immersive experience that changes dynamically according to the visitor's point of view and interest; in other words, according to what attracts the visitor during their gallery visit. These scenarios provide an experience based on adaptive information that can facilitate the visitors' access to the content, resulting in a more personal and meaningful experience.

The Quick Response (QR) code used in our exploration with Google Glass resulted an interesting way to facilitate and quicken the visitor's access to the content. The use of this functionality was not only convenient to facilitate the interactions (less actions to reach the content) but also because it allowed visitors' access to the information only when they were in proximity of the exhibit (when closed enough to scan the printed code). This implied the visitors' intention to receive information associated to the robot on display that got their attention. According to Osawa et al. [2007], who conducted several experiments with students using QR codes and mobile systems, the possibility of hiding information until it is needed facilitates the user's learning by reducing the cognitive load of learner's focus, thus reducing the demands on learners' working memory [Paas et al. 2003] and increasing their attention [Biocca et al. 2007]. QR codes are just one amongst many different technical possibilities to facilitate visitor interaction with the content associated with an object on display. Most likely, a new generation of proximity location technology called iBeacon[20] will be largely adopted in museums, enhancing the possibilities currently offered by the QR technology [He et al. 2015]. Generally speaking, this kind of technology consists of a Bluetooth sensor that can interact with your device, by delivering different levels of information according to the distance of your device from the sensor [Newman 2014]. The iBeacon technology makes it possible to deliver different information to the smart glass display according to the place visitors are in. When a visitor approaches a particular artifact – in correspondence of which is placed the iBeacon transmitter – the sensor detects the location and sends relevant digital content to the device visitors are wearing. Everything happens automatically without the need to trigger any command, just by the proximity of the visitor. In other words, the system pushes information to the visitor. This might open interesting opportunities in terms of design of personal visitor experience. For example, Raptis et al. [2005] stress how aspects related to personalization and context should be carefully considered when designing ubiquitous learning information systems for museum contexts, as they influence interaction.

The iBeacon is gaining momentum in museums. The positive feedback in terms of visitor experience and learning is confirmed by the growing research in this sector (for now mostly focused on mobile device interpretation), as has emerged from different projects and on-going experiments[21] with

[20]http://en.wikipedia.org/wiki/IBeacon.

[21]The School of Museum Studies at the University of Leicester UK (Dr. Giasemi Vavoula, Principal Investigator; Dr. Maria-Anna Tseliou, Research Fellow) is the academic partner of a project to develop iBeacons-based app to improve heritage interpretation

mobile devices [Browne 2014; Fiolet 2014]. For example, one of the most applauded was conducted at the Amgueddfa Cymru National Museum Wales, which has recently been the first national museum in the world to trial Apple iBeacon in conjunction with mobile apps[22]. The undergoing pilot project is taking place at the National Slate Museum in Llanberis, and aims to enhance the visitor experience by providing contextual information, enabling visitors to better discover and interact with the collection. During the first stage of the pilot project, the visitors received the digital content curated by the museum through their mobile devices while walking around the museum. The 25 iBeacons placed around the museum worked as a communication tool, which sent a signal (i.e., digital content) when visitors approached an object on display. The museum is now investigating specific experiences – such as learning, interpretation, and the use of bilingual and multilingual materials – favored by this digital system. There are several clues that suggest the possible large adoption of proximity systems in museum settings, including wearable technology such as smart glass. For example, last year the de Young Museum in San Francisco developed a project that adopts an interpretative strategy, offering the visitor a contextual information experience based on the integration of Google Glass and iBeacon.[23]

The study raises issues related to indoor navigation that, for example, can offer visitors the possibility to preselect and follow a guided tour. According to Filippini-Fantoni et al. [2011], indoor way finding with ubiquitous technologies such as smartphones has been (and still it is) a problematic issue for museums, which are still struggling to create compelling solutions on mobile platforms mainly due to the fact that "location aware technologies have proven to be expensive and problematic to install and maintain [. . .]." Recent technological enhancement and new sensors such as iBeacon [Martin et al. 2014] are offering museums promising tools to develop effective solutions to this never completely resolved problem. How will the specific form factor and particular position of the display influence smart glass way finding interaction paradigms? The first feedback from the participants of the experiment presented in this article and the scenarios that envision the future adoption of smart glasses[24] suggest interaction models that should superimpose navigational (visual and audio) clues and pathways supported by live positioning technology and navigation AR interfaces. In the Robotic Gallery, the participants would have benefited from an AR interface that provided visual directions to supplement the audio instructions. For example, AR could have been used to offer visitors a visual system constituted of turn-by-turn directions that dynamically indicated the direction on the map could have facilitated visitor exploration and movement to the next robot in the tour.

There are academic research projects conducted in different fields outside of the cultural heritage domain from which the next generation of navigation system for smart glasses might draw from Kim and Jun [2008], Fallah et al. [2013], Kasprzak et al. [2013], Xu et al. [2014], Yang et al. [2015], and Bettadapura et al. [2015]. For example, there are research projects on navigation systems, such Headlock and Navatar,[25] that aim to investigate how Google Glass could assist blinds providing audio feedback to guide the user toward a landmark [Fiannaca et al. 2014]. In a professional research project,

for the Leicester Castel (supported by NESTA, Art & Humanities Research Council and public funding by the National Lottery through Art Council of England). Other project partners: Locly (technology partner), Leicester City Council, Arts & Museums Service (arts partner), and Metro-Boulot-Dodo (content developer). On the press: http://advisor.museumsandheritage.com/features/leicester-castle-using-ibeacons-to-light-the-way-to-a-brighter-museum-experience; http://blog.locly.com/?p=1701.

[22]https://www.youtube.com/watch?v=ii_Na3AewKc&feature=youtu.be; http://www.museumwales.ac.uk/news/?article_id=840.

[23]"GuidiGO new storytelling platform enhances Keith Haring exhibition at the de Young Museum through Google Glass": http://blog.guidigo.com/blog/guidigo-new-storytelling-platform-enhances-keith-haring-exhibition-at-the-de-young-museum-through-google-glass/.

[24]Examples of concepts that envision interaction models that should superimpose navigational (visual and audio) clues: https://www.youtube.com/watch?v=B7YGD1If9z4; http://spreo.co/technology/google-glass-indoor-navigation-contextual-experiences; https://www.youtube.com/watch?v=V8ofTlynWPo.

[25]Navatar is an Indoor Navigation System for Blind Users using Google Glass https://www.youtube.com/watch?v=Q07oHm3zh04.

a company completed beta testing of indoor navigation with the Google Glass, adopting Bluetooth Beacon-based Indoor Navigation.[26] The navigation system can instruct the visitor to navigate to where they need to go with turn-by-turn directions and a voice guide. In the future, these types of indoor navigation systems mounted on smart glasses might offer museum practitioners a further interpretative tool to engage visitors through location-based and indoor navigation content experience.

Finally, from the interviews emerged the desire of the participants to take pictures or record videos from a "subjective point of view" and then share them with others through social networks. The correspondence of the camera and eye points of view, the liberation of the hands from the interaction with the device, and the camera being always ready to shoot (even with a quick wink), allow the visitor to capture their own perspective, and share it. In their seminal work about visitor experience in museum settings, Falk and Dierking [2012] describe the importance of the "Social Dimension of Learning," underlining the value of designing for experiences that permits sharing socially and physically. The social dimension of visitor experience within museums has been largely considered in designing mobile visitor experiences for museums in the last decade [Gammon and Burch 2008; Proctor 2010]. In parallel, there has been a growing interest in the use of social media platforms [Russo et al. 2006; Proctor 2010], and Social networks such as Twitter and Facebook, along with websites, are now being seen as surrogates for a physical museum experience" [NMC Horizon Report 2015 Museum Edition].

But this example just scratches the surface of wearable-glass social-media possibilities in the future. For now, wearable head-mounted displays are primarily a visual medium and, for this reason, text-focused social media does not complement such technology, as reading or writing long posts is still arduous in terms of interaction (also considering that museums are not the ideal place to use voice input feature). First of all, the form factor changes the way users receive messages because the optical see-through head-mounted display is smaller and it displays information in a different position than a typical smart phone; as a consequence, the reduced size limits the amount of information the user can comfortably read [Kiyokawa 2008]. Second, the interaction constraints, due to still-limited methods of input, might bring (at least initially) the design of micro-interactions such as "likes" rather than relatively long texts. With a limited screen space and different interaction on glass devices, new social media might emerge that will adapt to new needs as wearable technology will probably modify social media platforms as we know them: referencing McLuhan [1994], as the medium changes, the message must change as well.

6. FURTHER RESEARCH

In this article, I adopted a qualitative approach with the aim of bringing reflections to inform the design of smart-glass-enhanced visitor experience. I discussed the findings by comparing and enriching the six main themes that have emerged from the study with extant literature on ubiquitous interpretative systems for cultural heritage. This critical review of the literature can offer museum practitioners, designers, and developers useful design insights and references that might contribute implementing innovative smart-glass-enhanced visitor experience. Further research focused on developing, implementing, and testing specific functionalities would form an important advancement to my study. It would also be of interest to further investigate other aspects of smart-glass-enhanced visitor experience through similar qualitative approaches to that adopted in this study. As discussed in this article, the adaptive content is an aspect of the personalization of cultural heritage information that will characterize the future generation of wearable technology in museums. As the starting point of a possible future strand of research, I would suggest considering the research conducted by Ardissono et al. [2012] on the use of personalized technology to connect cultural heritage to visitor experience; the

[26]http://spreo.co/industry-venue-locations/hospital-indoor-navigation-positioning.

recent article on location-based mixed and augmented reality storytelling in which Azuma [2015] sees a further advancement in digital technology for cultural heritage by enabling digital systems "to tell stories in new and potentially more compelling ways"; and, finally, the innovative concept of "Adaptive Augmented Reality" presented by Damala et al. [2012] which promotes an approach aiming to enhance the interpretative opportunity offered by AR with visitor-tailored adaptation of the content combining visual, audio, and physiological sensors. This requires further research that should not only focus on the improvement of the technology per se, but also upon the experiences it delivers to visitors.

7. CONCLUSION

Wearable technology in general is gaining momentum. In particular, Google Glass and other smart glass devices have recently brought a growing interest towards the adoption of this particular media both in everyday life and specific sectors. Following this trend, the museum world is paying great attention to the use of smart glasses in museums for enhancing the visitor experience.

The features such as sensors and connectivity, and a new form factor (small display located in proximity of the user's eye) provide a technology to design for new kind of visitor experience that, for example, is more immersive, since visitors can stay more aware of their context when receiving information.

The content has to be tailored considering the new characteristics of this particular type of interpretive device and designed in accordance with the different interaction modalities this new type of wearable devices puts at our disposal. Augmented Reality seems to be one of the most promising ways of conveying content through smart glasses and provide visitors with immersive forms of interaction, mainly for its capacity to combine the real and the virtual and being interactive in real time within the scene. Future scenarios envision visitors manipulating "augmented content" through visitor inputs enhanced by gestures that are recognised by gesture-recognition functionalities integrated into smart glass devices. It will be crucial to design interactions that support experiences fully integrated with the context, for example, by providing context-aware information according to visitors' visual orientation, location in the gallery, and proximity to the object on display.

Not only the gallery context has to be considered in the design, but also the social domain in which social media platforms support visitors in sharing their experience and information, literally from their own perspective.

With the reflections that emerged from the design exploration and related references presented in this study, I hope to bring a further contribution to the design of latest generation of smart glass apps, providing also insights for further studies and projects.

ACKNOWLEDGMENTS

I would like to express my gratitude to the participants that afforded me their time for this study.

I would like to thank in particular: Professor John Durant – Science, Technology, and Society Program at the Massachusetts Institute of Technology and director of the MIT Museum; Allan Doyle – Director of Technology at the MIT Museum and Co-director of the MIT Museum Studio; and Chun Kit Chan – MIT Media Lab exchange student in Electrical Engineering and Computer Science Department at the Massachusetts Institute of Technology.

The author is grateful to Dr. Deborah Douglas (MIT Museum curator) and Kurt Hasselbalch (MIT Museum Hart Nautical Collections) for the digital content they provided.

REFERENCES

A. Adams, P. Lunt, and P. Cairns. 2008. A qualititative approach to HCI research. In *Research Methods for Human-Computer Interaction*, P. Cairns and A. Cox (Eds.). Cambridge University Press, 138–157.

J. Alexander, J. Barton, and C. Goeser. 2013. Transforming the art museum experience: Gallery one. In *Museums and the Web 2013*, N. Proctor and R. Cherry (Eds.). Silver Spring, MD. Retrieved July 7, 2015 from http://mw2013.museumsandtheweb.com/paper/transforming-the-art-museum-experience-gallery-one-2.

L. Ardissono, T. Kuflik, and D. Petrelli. 2012. Personalization in cultural heritage: The road travelled and the one ahead. *User Modeling and User-Adapted Interaction*, 22, 1–2, 73–99.

ARtSENSE. 2012. Augmented RealiTy Supported adaptive and personalized Experience in a museum based on processing real-time Sensor Events. Retrieved December 11, 2015 from http://cordis.europa.eu/project/rcn/97475_en.html.

R. Azuma. 1997. A survey of augmented reality. *Presence*, 6, 4, 355–385.

R. Azuma. 2015. *Location-Based Mixed and Augmented Reality Storytelling.* B. Woodrow (Ed.). Chapter 11 in the book Fundamentals of Wearable Computers and Augmented Reality, 2^{nd} Ed., CRC Press, 259–276.

A. Barry, J. Trout, P. Debenham, and G. Thomas. 2012. Augmented reality in a public space: The natural history museum, london. *Computer*, 7, 42–47.

P. Bazeley and J. Kristi. 2013. *Qualitative Data Analysis with NVivo*. Second Edition. SAGE Publications, London.

V. Bettadapura, I. Essa, and C. Pantofaru. 2015. Egocentric field-of-view localization using first-person point-of-view devices. In *Applications of Computer Vision (WACV), 2015 IEEE Winter Conference*, 626–633.

BGC Google Glass Team. 2014. BGC Gallery Google Glass Exhibition Interpretation Pilot Project. Retrieved December 11, 2015 from http://www.bgc.bard.edu/gallery/glass.html.

BGC. 2014. Bard Graduate Center Gallery: Google Glass Pilot Project. Retrieved December 11, 2015 from http://www.bgc.bard.edu/images/content/1/6/16042.pdf.

F. Biocca, C. Owen, A. Tang, and C. Bohil. 2007. Attention issues in spatial information systems: Directing mobile users' visual attention using augmented reality. *Journal of Management Information Systems*, 23, 4, 163–184.

M. Birks, Y. Chapman, and K. Francis. 2008. Memoing in qualitative research probing data and processes. *Journal of Research in Nursing*, 13, 1, 68–75.

D. Boyer and J. Marcus. 2011. Implementing mobile augmented reality applications for cultural institutions. In *Museums and the Web 2011: Proceedings*, J. Trant and D. Bearman (Eds.). Archives & Museum Informatics, Toronto, 5–9.

J. Browne. 2014. Positioning Visitors with iBeacons (October 14, 2014). Retrieved December 11, 2015 from https://www.brooklynmuseum.org/community/blogosphere/2014/10/14/positioning-visitors-with-ibeacons.

G. Cameron, W. Rogers, M. Apperley, and S. Jones. 2015. Reading text in an immersive head-mounted display: An investigation into displaying desktop interfaces in a 3D virtual environment. In *Proceedings of the 15^{th} New Zealand Conference on Human-Computer Interaction*, ACM, 3–4 September, Hamilton NZ, 9–16.

P. Chamberlain, P. Gardner, and R. Lawton. 2007. Shape of things to come. In *Design Research Now*, R. Michel (Ed.). Birkhäuser Base. 99–116.

J. Chauhan, A. Mahanti, and M. Kaafar. 2014. Towards the era of wearable computing? In *Proceedings of the 2014 CoNEXT on Student Workshop*, ACM, December 2–5, Sydney, 24–25.

Cnet. 2013. Meta Glasses are the future of computing (August 9, 2013). Retrieved December 14, 2015 from https://www.youtube.com/watch?v=b7I7JuQXttw.

A. Damala and N. Stojanovic. 2012. Tailoring the adaptive augmented reality (A2R) museum visit: Identifying cultural heritage professionals' motivations and needs. In *2012 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities (ISMAR-AMH)*, November 5–8, Atlanta, GA, 71–80.

A. Damala, I. Marchal, and P. Houlier. 2007. Merging augmented reality based features in mobile multimedia museum guides. In *Anticipating the Future of the Cultural Past, CIPA Conference 2007*, 1–6 October, Athens, Greece, 259–264.

A. Damala, N. Stojanovic, T. Schuchert, J. Moragues, A. Cabrera, and K. Gilleade. 2012. Adaptive augmented reality for cultural heritage: ARtSENSE project. In *Progress in Cultural Heritage Preservation.* Springer Berlin Heidelberg, 746–755.

A. Damala, P. Cubaud, A. Bationo, P. Houlier, and I. Marchal. 2008. Bridging the gap between the digital and the physical: Design and evaluation of a mobile augmented reality guide for the museum visit. In *Proceedings of the 3^{rd} International Conference on Digital Interactive Media in Entertainment and Arts*, DIMEA'08, ACM, September 10–12, Athens, Greece, 120–27.

A. Damala. 2013. An introduction to augmented reality and cultural heritage for curators, art historians and museum educators. In *La Cocina valenciana del Museo Nacional de Artes Decorativas*. Secretaría General Técnica, Centro de Publicaciones Ministerio de Educación, Cultura y Deporte, 120–133.

L. de' Medici. 2015. Top 10 Implantable Wearables Soon To Be In Your Body (October 27, 2015). Retrieved December 10, 2015 from https://wtvox.com/3d-printing-in-wearable-tech/top-10-implantable-wearables-soon-body.

J. H. Falk and L. D. Dierking. 2012. *Museum Experience Revisited*. Left Coast Press, Walnut Creek, CA.

N. Fallah, I. Apostolopoulos, K. Bekris, and E. Folmer. 2013. Indoor human navigation systems: A survey. *Interacting with Computers*, 25, 1, 21–33.

A. Fiannaca, I. Apostolopoulous, and E. Folmer. 2014. October. Headlock: A wearable navigation aid that helps blind cane users traverse large open spaces. In *Proceedings of the 16th International ACM SIGACCESS Conference on Computers & Accessibility*. 20–22 October, Rochester, NY, USA. 19–26.

S. Filippini-Fantoni, S. McDaid, and M. Cock. 2011. Mobile devices for orientation and way finding: The case of the British Museum multimedia guide. In *Museums and the Web 2011: Proceedings.* Retrieved October 11, 2015 from *http://conference.archimuse.com/mw2011/papers/mobile˙devices˙for˙wayfinding*.

A. Findeli, D. Brouillet, S. Martin, Ch. Moineau, and R. Tarrago. 2008. Research through design and transdisciplinarity: A tentative contribution to the methodology of design research. In *Focused - Current Design Research Projects and Methods*, B. Minder (Ed.). 67–94.

E. Fiolet. 2014. GuidiGo powers first in-gallery tour on Google Glass at De Young Museum (January 12, 2014). Retrieved December 11, 2015 from http://www.ubergizmo.com/2014/12/guidigo-powers-first-in-gallery-tour-on-google-glass-at-de-young-museum.

P. Gallagher. 2014. How Google Glass could change the way we view art. *The Independent* (June 1, 2014). Retrieved December 11, 2015 from http://www.independent.co.uk/life-style/gadgets-and-tech/news/how-google-glass-could-change-the-way-we-view-art-9468326.html.

B. Gammon and A. Burch. 2008. Designing mobile digital experiences. In *Digital Technologies and the Museum Experience: Handheld Guides and Other Media*. L. Tallon (Ed.). Rowman Altamira, Lanham, MD. 35–62.

Q9 E. Giaccardi. 2012. *Heritage and social media: Understanding Heritage in a Participatory Culture*. New York, NY, Routledge.

Google. 2015a. GDK Quick Start. Retrieved December 14, 2015 from https://developers.google.com/glass/develop/gdk/quick-start.

Google. 2015b. GDK Quick Start. Retrieved December 14, 2015 from https://developers.google.com/glass/design/principles.

T. Hall, L. Ciolfi, L. Bannon, M. Fraser, S. Benford, J. Bowers, C. Greenhalgh, S. O. Hellström, S. Izadi, H. Schnädelbach, and M. Flintham. 2001. The visitor as virtual archaeologist: Explorations in mixed reality technology to enhance educational and social interaction in the museum. In *Proceedings of the 2001 Conference on Virtual Reality, Archeology, and Cultural Heritage*, November 28–30, Athens, Greece, 91–96.

B. Hammersley. 2013. Wearables: The Third Wave of Computing. WIRED UK. January. Retrieved November 14, 2015 from http://www.wired.co.uk/magazine/archive/2014/01/features/the-third-wave-of-computing.

M. Hassenzahl, S. Diefenbach, and A. Göritz. 2010. Needs, affect, and interactive products–Facets of user experience. In *Interacting with Computers* 22, 5, 353–362.

Z. He, B. Cui, W. Zhou, and S. Yokoi. 2015. July. A proposal of interaction system between visitor and collection in museum hall by iBeacon. In *2015 10th International Conference Computer Science & Education (ICCSE).* IEEE. July 22–24, Cambridge University, UK. 427–430.

E. Hooper-Greenhill, J. Dodd, T. Moussouri, C. Jones, C. Pickford, C. Herman, M. Morrison, J. Vincent, and R. Toon. 2003. Measuring the outcomes and impact of learning in museums, archives and libraries: The learning impact research project end of project paper. *Published by the Research Centre for Museums and Galleries (RCMG)*, School of Museum Studies at the University of Leicester, UK. Retrieved December 14, 2015 from https://lra.le.ac.uk/handle/2381/65.

F. Joep. 2007. Research through design: A camera case study. In *Design Research Now*, R. Michel (Ed.). Birkhäuser, Basel. 135–54.

S. Kasprzak, A. Komninos, and P. Barrie. 2013. Feature-based indoor navigation using augmented reality. In *9th International Conference on Intelligent Environments (IE), ACM.* July 18–19, Athen, Greece, 100–107.

J. Keil, L. Pujol, M. Roussou, T. Engelke, M. Schmitt, U. Bockholt, and S. Eleftheratou. 2013. A digital look at physical museum exhibits: Designing personalized stories with handheld augmented reality in museums. In *Digital Heritage International Congress (DigitalHeritage).* IEEE, 2. 28 November – October 1, Marseille, France, 685–688.

J. Keil, T. Engelke, M. Schmitt, U. Bockholt, and L. Pujol. 2014. Lean in or lean back? Aspects on interactivity and mediation in handheld augmented reality in the museum. In *12th Eurographics Workshops on Graphics and Cultural Heritage (GCH)*, R. Klein and P. Santos (Eds.). 6–8 October, Darmstadt.

J. Kim and H. Jun. 2008. Vision-based location positioning using augmented reality for indoor navigation. *Consumer Electronics, IEEE Transactions on*, 54, 3, 954–962.

K. Kiyokawa. 2008. An introduction to head mounted displays for augmented reality. In *Emerging Technologies of Augmented Reality: Interfaces and Design*. T. Haller, M. Billinghurst, and B. Thomas (Eds.). Idea group Publishing, London. 43–63.

K. Kiyokawa. 2012. Trends and vision of head mounted display in augmented reality. In *2012 International Symposium on Ubiquitous Virtual Reality IEEE*. 22–25 August, Adaejeon, Korea. 14–17.

E. Klopfer, 2008. *Augmented learning: Research and Design of Mobile Educational Games*. Mit Press. Cambridge, MA.

I. Koskinen, J. Zimmerman, T. Binder, J. Redstrom, and S. Wensveen. 2011. *Design Research Through Practice: From the Lab, Field, and Showroom*. 1st ed. Morgan Kaufmann. Waltham, MA.

S. Kvale. 2008. *Doing Interviews*. SAGE. London.

G. A. Lee, A. Dunser, S. Kim, and M. Billinghurst. 2012. CityViewAR: A mobile outdoor ar application for city visualization. In *2012 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities (ISMAR-AMH)*, November 5–8, Atlanta, GA, 57–64. Q10

C. M. Leue, T. Jung, and D. Tom Dieck. 2015. Google glass augmented reality: generic learning outcomes for art galleries. In *Information and Communication Technologies in Tourism 2015. Proceeding of the International Conference in Lugano, February 2-6, 2015*. Springer International Publishing, Switzerland. 463–476.

W. Lu, L. Nguyen, T. Chuah, and E. Do. 2014. Effects of mobile AR-enabled interactions on retention and transfer for learning in art museum contexts. In *2014 IEEE International Symposium on Mixed and Augmented Reality-Media, Art, Social Science, Humanities and Design (ISMAR-MASH'D)*. September 10–12, Munich, Germany. 3–11.

A. Lucero, K. Lyons, A. Vetek, T. Järvenpää, S. White, and M. Salmimaa. 2013. Exploring the interaction design space for interactive glasses. In *CHI'13 Extended Abstracts on Human Factors in Computing Systems ACM*. April 27 - May 02, Paris, France. 1341–1346.

P. Martin, B. Ho, N. Grupen, S. Muñoz, and M. Srivastava. 2014. An iBeacon primer for indoor localization: Demo abstract. In *Proceedings of the 1st ACM Conference on Embedded Systems for Energy-Efficient Buildings*. November 5–6, Memphis, USA. 190–191.

M. Mason. 2012. The dimensions of the mobile visitor experience: Thinking beyond the technology design. *International Journal of the Inclusive Museum*, 5, 3, 51–72

P. May. 2015. Museum 2.0: Google glass, apps and interactive exhibits change the experience. *San Jose Mercury News (February 1, 2015)*. Retrieved December 11, 2015 from http://www.mercurynews.com/business/ci_27234868/museum-2-0-google-glass-apps-and-interactive.

M. McLuhan. 1994. *Understanding Media: The Extensions of Man*. MIT press. Cambridge, MA.

E. Merrit. 2015. Trendswatch 2015. In *Center for the Future of Museums*. Retrieved December 14, 2015 from http://www.aam-us.org/resources/center-for-the-future-of-museums/projects-and-reports/trendswatch/trendswatch2015.

META. 2015. Retrieved December 14, 2015 from https://www.getameta.com.

P. Milgram and F. Kishino. 1994. A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems*, 77, 12, 1321–1329.

O. Muensterer, M. Lacher, C. Zoeller, M. Bronstein, and J. Kübler. 2014. Google Glass in pediatric surgery: An exploratory study. *International Journal of Surgery*, 12, 4, 281–289.

Museo Egizio. 2013. Googleglass4Lis The Museum for Deaf-Mute People (February 6, 2014). Retrieved December 20, 2015 http://www.museoegizio.it/en/googleglass4lis-the-museum-for-deaf-mute-people.

N. Newman. 2014. Apple iBeacon technology briefing. In *Journal of Direct, Data and Digital Marketing Practice* 15, 3, 222–25.

NMC Horizon Report. 2015 Museum Edition. Retrieved December 14, 2015 from http://www.nmc.org/publication/nmc-horizon-report-2015-museum-edition.

D. Novak, M. Wang, and V. Callaghan. 2012. Looking in, looking out: A discussion of the educational. In *Educational Stages and Interactive Learning: From Kindergarten to Workplace Training: From Kindergarten to Workplace Training*, IGI Global, Hershey, PA. 92–106.

Y. Ohta and H. Tamura. 1999. *Mixed Reality: Merging Real and Virtual Worlds*. Springer-Verlag New York, Inc. Secaucus, NJ.

N. Osawa, K. Noda, S. Tsukagoshi, Y. Noma, A. Ando, T. Shibuya, and K. Kondo. 2007. Outdoor education support system with location awareness using RFID and symbology tags. *Journal of Educational Multimedia and Hypermedia*, 16, 4, 411–428.

F. Paas, A. Renkl, and J. Sweller. 2003. Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, 38, 1, 1–4.

M. Q. Patton. 1990. *Qualitative Evaluation and Research Methods (2nd Ed.)*. Sage Publications, Inc. Thousand Oaks, CA.

I. Pedersen. 2013. *Ready to Wear: A Rhetoric of Wearable Computers and Reality-Shifting Media*. Parlor Press. Anderson, SC.

T. Pederson, E. Janlert, and D. Surie. 2010. Towards a model for egocentric interaction with physical and virtual objects. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*. October 16–20. Reykjavik, Iceland. 755–758.

N. Proctor. 2010. Digital: Museum as platform, curator as champion, in the age of social media. *Curator: The Museum Journal*, 53, 1, 35–43.

D. Raptis, N. Tselios, N. Avouris. 2005. Context-based design of mobile applications for museums: A survey of existing practices. In *Proceedings of the 7^{th} International Conference on Human Computer Interaction with Mobile Devices & Services* ACM. September 19–22, Salzburg, Austria. 153–160.

S. Rattanarungrot and M. White. 2014. A service-oriented mobile augmented reality architecture for personalized museum environments. In *2014 International Conference on Virtual Systems & Multimedia (VSMM)*. IEEE. December 9–12, Hong Kong. 277–284.

S. Rattanarungrot, M. White, Z. Patoli, and T. Pascu. 2014. The application of augmented reality for reanimating cultural heritage. In *Virtual, Augmented and Mixed Reality. Applications of Virtual and Augmented Reality*. Springer International Publishing. Orlando, FL. 85–95.

T. Rhodes and S. Allen. 2014. Through the looking glass: How Google Glass will change the performing arts. In *Arts Management and Technology Laboratory*, 1–12.

L. Richards. 2009. *Handling Qualitative Data: A Practical Guide (2nd Ed.)*. SAGE Publications Ltd. London.

Q11 H. Rubin and I. Rubin. 2011. *Qualitative Interviewing: The Art of Hearing Data*. Sage. London.

A. Russo, J. Watkins, L. Kelly, and S. Chan. 2006. How will social media affect museum communication? In *Nordic Digital Excellence in Museums (NODEM)*, December 7–9, Oslo, Norway. 1–8.

M. Sarwar and T. R. Tariq Soomro. 2013. Impact of smartphones on society. *European Journal of Scientific Research* 98, 2,
Q12 216–226.

F. Schumacher. 2014. Wearable implants for the daring and for those in need (July 22, 2014). Retrieved December 5, 2015 from http://libraryblogs.is.ed.ac.uk/blog/2014/12/16/google-glass-gaming-and-gallimaufry.

F. Sparacino. 2002. The museum wearable: Real-time sensor-driven understanding of visitors' interests for personalized visually-augmented museum experiences. In *Museums and the Web 2002*. Retrieved October 2, 2015 from http://www.museumsandtheweb.com/mw2002/papers/sparacino/sparacino.html.

J. P. Stappers. 2007. Doing design as a part of doing research. In *Design Research Now*, R. Michel (Ed.). Birkhäuser Basel. 81–91.

N. Stimler and R. Stein. 2014. Google Glass, wearable technology and the future of museums. Presented at *Museums and the Web 2014*. Retrieved July 21, 2015 from http://mw2014.museumsandtheweb.com/proposals/google-glass-wearable-technology-and-the-future-of-museums.

Dan Sung. 2015. What is wearable tech? Everything you need to know explained. Wearable tech, fitness trackers and smartwatches explained (August 3, 2015). Retrieved December 8, 2015 from http://www.wareable.com/wearable-tech/what-is-wearable-tech-753.

A. Tillon, I. Marchal, and P. Houlier. 2011. Mobile augmented reality in the museum: Can a lace-like technology take you closer to works of art? In *2011 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities (ISMAR-AMH)*, October 26–29, Basel, Switzerland, 41–47.

A. Tillon, I. Marchand, J. Laneurit, F. Servant, I. Marchal, and P. Houlier. 2010. A day at the museum: An augmented fine-art exhibit. In *2010 IEEE International Symposium on Mixed and Augmented Reality-Arts, Media, and Humanities (ISMAR-AMH)*, October 13–16, Seoul, South Korea. 69–70.

D. W. Turner III. 2010. Qualitative interview design: A practical guide for novice investigators. *The Qualitative Report*, 15, 3, 754–760.

D. Van Krevelen and R. Poelman. 2010. A survey of augmented reality technologies, applications and limitations. *International Journal of Virtual Reality*, 9, 2, 1–20.

E. Verón and M. Levasseur. 1989. *Ethnographie de l'exposition: L'espace, Le Corps Et Le Sens*. Centre Georges Pompidou, Bibliothèque publique d'information.

B. Wasik. 2014. Why wearable tech will be as big as the smartphone. *WIRED UK*. December 17. Retrieved December 10, 2015 from http://www.wired.com/2013/12/wearable-computers.

G. Willshaw. 2014. Google Glass, gaming and Gallimaufry (December 16, 2014). Retrieved December 10, 2015 from http://libraryblogs.is.ed.ac.uk/blog/2014/12/16/google-glass-gaming-and-gallimaufry.

M. Wohlsen. 2014a. The only way to save Google Glass is to kill it. *WIRED*, November 25. Retrieved December 10, 2015 from http://www.wired.com/2014/11/way-save-google-glass-kill.

M. Wohlsen. 2014b. Google could dominate wearables with glass OS. *WIRED UK*. November 27. Retrieved December 10, 2015 from http://www.wired.co.uk/news/archive/2014-11/26/kill-google-glass.

A. Woodruff, P. Aoki, A. Hurst, and M. Szymanski. 2001. September. Electronic guidebooks and visitor attention. In *ICHIM*, 1, 437–454.