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Mapping Requirements for the Wearable Smart Glasses Augmented Reality Museum Application

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ABSTRACT:

Purpose

Recent advancements in wearable computing offer opportunities for art galleries to provide a unique experience. However, in order to ensure successful implementation of this new technology in the visitor industry, it is essential to understand user requirements from a visitor's point of view. Therefore, the aim of this paper is to investigate visitors' requirements for the development of a wearable smart glasses Augmented Reality (AR) application in the museum and art gallery context.

Design/Methodology/Approach

Interviews with 28 art gallery visitors were conducted and an affinity diagram technique was used to analyze the interviews.

Findings

The findings reveal that wearable AR is in its infancy and that technical and design issues have to be overcome for a full adoption. It reveals that content requirement, functional requirement, comfort, experience and resistance are important when developing and implementing the wearable AR application in the museum and art gallery context.

Originality/Value

Mapping user requirements in the wearable smart glasses AR context using an affinity diagram is a new approach and therefore contributes to the creation of knowledge in the tourism domain. Practically, the area of wearable technologies and AR within the tourism and visitor industry context is still relatively unexplored and the present paper provides a first foundation for the implementation of wearable smart glasses AR applications in the museum and art gallery context.

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Keywords: Wearable Augmented Reality, Smart glasses, User Requirements, Manchester Art Gallery, Affinity Diagram

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Introduction

Mobile computing has experienced an immense growth over the last decade with the trend moving towards the next generation of even smaller and pervasive wearable computing that is integrated into users' daily lives and jobs (Ham et al., 2014; Edmondson et al., 2014). The advancements in sensor technologies have enabled companies to develop unencumbering and non-invasive devices such as smart watches and glasses (Kahn, 2013). Especially with the development of Head-Mounted Displays (HMD), wearable computing has become more ubiquitous and user friendly (Funk et al., 2014). Google Glass is a new and innovative wearable smart glasses that completed its developer program in January 2015 and is now at the last stage towards releasing a consumer version. One of few studies which explored Google Glass and augmented reality (AR) was conducted by Rauschnabel et al. (2015, p. 644) and concluded "smart glasses offer a wealth of avenues for future research to academic inquiry". Therefore, at this point in time, research is particularly important for museums and art galleries to understand the opportunities of wearable smart glasses AR.

The recent advancements in wearable computing offer new opportunities for visitor attractions such as museums and art galleries to provide a unique visitor experience. Through the use of AR, visitor attractions are able to create engaging content which is overlaid onto objects or artworks (Jung et al., 2015; Olsson et al., 2012). Traditionally more smartphone-based, the introduction of wearable devices provides users with a hand-free opportunity to receive content while travelling or visiting public spaces. Within the software development community, according to Patrício et al. (2003, p. 472), there is an increasing awareness and acceptance of "the importance of user requirements and usability for the success of user interfaces". Therefore, in order to develop and implement a functioning and well-perceived wearable AR application, it is essential to identify user requirements, as users will be the ones to accept or reject the application and so determine its success (Patrício et al., 2003). Previous research in the mobile context identified content, function and other requirements (Dinh et al., 2013; Karahasanović et al., 2009; Kenteris et al., 2009), however research investigating these requirements in the wearable AR context is limited. Nevertheless, through the identification of user requirements, developers are able to identify how users perform certain tasks and what is important to them, as well as what they dislike in an application (Ginsburg, 2010). Due to the novelty aspect of wearable computing, there have been few research attempts to examine user requirements for wearable AR. However, studies on user requirements in the wearable AR in the context of museum and art galleries are limited and therefore it is important to lay the groundwork for application development through the identification of user requirements. Hereby, it is particularly important to incorporate users' points of view.

Latest advancements in information technologies have made the use of mobiles devices for everyday lives a norm, making it ever more important to integrate latest technological innovations into museum exhibitions to enhance interaction (American Alliance of Museums, 2014). Tom Dieck and Jung (2015) revealed that AR enables tourists to receive a dynamic and interactive museum and art gallery experience by bringing history and knowledge to life.

According to Murphy (2015), the use of technologies such as AR will play the most important role for future curators as more and more visitors expect the incorporation of these experiences into the museum visit. Furthermore, Radsky (2015) acknowledged museums which manage to create seamless AR applications, merging digital information with the museum and art gallery exhibit, are expected to be more competitive in the long-term. However, previous research revealed that art gallery visitors perceived mobiles cumbersome and unpractical with visitors wanting to view and appreciate paintings naturally with a hand free approach without the disturbance of the mobile phone (Leue et al., 2014). Therefore, it is crucial to identify user requirements of a wearable smart glasses AR application to meet the needs of art gallery visitors in the future as an alternative solution. Due to the lack of research in the context of museum and art gallery wearable smart glasses AR applications (tom Dieck and Jung, 2015), particularly from a visitor's point-of-view, this study aims to identify user requirements of a wearable smart glasses AR application in the museum and art gallery context.

Literature Review

Augmented Reality in Museums and Art Galleries

AR remains a 'buzzword' in the professional and research community and is increasingly getting attention in the media through upcoming AR mobile applications (Sterling, 2014). While the use for AR is wide ranging, it was generally defined as the enhancement of the real environment by overlaying computer-generated content (Jung et al., 2015). King et al. (2009) argued that AR though effectively employed in the industry, has made little contribution to benefit the public. Tourism was identified as one of the economy-enhancing industries for many countries (Holloway, 2002). One of the main topics of tourism development has been argued to be sustainability, which highlights areas within the sustainable development and growth of heritage sites (Williams and Ponsford, 2009). Technology has therefore been identified in many studies as one way for destinations to gain competitive advantage, particularly within the cultural heritage sector (Stanco et al., 2011; Chhabra, 2010; Kalay, 2008). For example, Anderson et al. (2010) suggested the implementation of interactive virtual gaming in order to increase competitiveness of cultural heritage sites as well as enhance the learning outcomes of visitors. AR applications in tourism are currently increasing with most tourism-related applications being based on the GPS sensor of mobile devices and providing information on the immediate surrounding (Yovcheva et al., 2012). It was argued that due to its capability, AR would logically be highly beneficial for the tourism industry (Fritz et al., 2005). Olsson et al. (2013) suggested AR capable devices be developed into the next generation tourist guide due to the potential to personalize information freely according to the user's interest. Chang et al. (2014) conducted a study on mobile AR in the art gallery context and found that AR is beneficial for the understanding and appreciation of art, while at the same time visitors were not distracted by the novelty of the technology. However, the exploration of using AR with wearable devices such as Google Glass in the context of museums and art galleries is limited. Therefore, this study will provide an insight into a visitor experience study for implementing a wearable AR tourism application in museums and art galleries.

Wearable Computing

McNaney et al. (2014, p. 1) suggested that "one of the major recent wearable computing breakthroughs is Google's new 'eyewear computer'… referred to as Glass". According to Holey and Gaikwad (2014), the main purpose of Google Glass is the hand-free display of knowledge.

Google's focus for its Glass project is particularly on niche industry applications such as medical and manufacturing as well as museums and art galleries. For HMD, an optic is placed on a glass frame in front of the users' eye to create a virtual image for the user. This allows the projection of augmented reality (AR) into the real world (Lucero et al., 2013; Rhodes & Allen, 2014). As a consequence of these advancements, wearable computing is starting to be considered easy to use and implementable into urban cultural heritage attractions. Cucchiara and Del Bimbo (2014) researched visitors' experience to museums, exhibitions and cultural heritage sites and discussed the potential of implementing wearable devices to receive relevant information. It was found that implementation needs to be planned carefully to ensure the enhancement of the experience without ending up "alienating visitors from one another" (Cucchiara and Del Bimbo, 2014, p. 82). In addition, it was revealed that the experience has to be non-invasive and that visitors have to be in control of their wearable AR experience at all times throughout the cultural heritage journey (Cucchiara and Del Bimbo, 2014).

Previous research within the cultural heritage context found that traditional devices such as audio guides or mobiles were perceived cumbersome and unpractical by visitors, while smart glasses provide visitors with a hand free approach of receiving enhanced information (Leue et al., 2014). This was supported by Rhodes and Allen (2014) and Ferguson (2013) who acknowledged that smart glasses will benefit cultural heritage sites through the overlay of digital content into visitors direct experience. Visitors are enabled to view and appreciate paintings naturally without the disturbance of the mobile phone, while smart glasses can provide information when desired for a better experience (Leue et al., 2014). In addition, Dalens et al. (2014) described the potential of recognizing paintings within art galleries through smart glasses. However to date, only few studies qualitatively explored the area of wearable smart glasses AR within the cultural heritage tourism context.

Augmented Reality User Requirements

Since the field of wearable AR user requirements is still considered a new area, literature in wearable AR user requirements is still limited. Therefore, identifying user requirements in the mobile computing context was regarded as the most suitable guiding point to look at user requirements in the context of this study. For the purpose of this literature review, user requirements are divided into content, function and other requirements such as comfort, experience and resistance.

Insert Table 1 about here

Content requirements

In the tourism mobile context, a number of scholars identified that relevant and updated information on surrounding areas is one of the most important content requirements (Turner et al., 2007; Wang and Liao, 2007; Gafni, 2008; Karahasanović et al., 2009; Kenteris et al., 2009; Gebauer et al., 2010). Furthermore, Zheng and Pulli (2005) pointed out the importance of accessibility claiming as technology develops further, it was more significant to enable instant access to information through hardware and software. According to An et al. (2008), the link to widely used social media platforms such as Facebook and Twitter was seen to be inevitable as people increasingly desired to be connected to others with disregard to their current location. Gafni (2008) further noted that trends were shifting towards personalized content as more people

owned smartphones. This was considered crucial as the development of mobile hardware was shifting from smartphones to wearables.

Research question 1:
What are the key content requirements applicable to wearable smart glasses AR applications in the museum and art gallery context?

Function requirements
Simplicity as well as user interface design were identified as two of the most reoccurring function requirements throughout software and mobile computing (Gafni, 2008; Herzwurm and Schockert, 2003; Pulli et al., 2007; Tan et al., 1998; Zheng and Pulli, 2005). It was suggested to keep user interfaces easy to understand and interact with. In addition, user interfaces should serve the purpose they were designed for without having to implement complicated software and application design as they were generally regarded as a deterrent for users (Gafni, 2008). Patrício et al. (2003, p. 472) acknowledged that "time to learn, speed of performance, rate of errors, and user retention [as well as] simplicity, clarity of function, and visibility" are user requirements of e-services. On the other hand, Herzwurm and Schockert (2003) suggested that software developers need to consider the size of the application if users were required to download specific elements or content.

Research question 2:
What are key function requirements applicable to wearable smart glasses AR applications in the museum and art gallery context?

Other requirements
With the development of current wearable hardware such as Google Glass as well as the transparency of the Internet due to widely spread social networks such as Facebook, privacy and security issues were still considered crucial for new applications and one of the main factors that lead to resistance of accepting latest technologies (Zheng and Pulli, 2005). Therefore, it was suggested that data privacy issues were respected when developing mobile applications in particular. Experience-wise, numerous scholars identified that applications need to be considered useful in order to be accepted as an enhancer of the experience. Therefore, usefuless is considered one of the key requirements of mobile applications. In addition, applications have to add value to the tourist experience in order to be used frequently which is considered another requirement (Karahasanović et al., 2009; Gebauer et al., 2010; Dinh et al., 2013). Finally, Karahasanović et al. (2009) revealed that entertainment is a user requirement of mobile applications. In addition, literature argued that mobile devices needed to become more efficient and convenient for everyday life in order to assist time-pressured people to complete their daily tasks effectively (Pulli et al., 2007).

Research question 3:
What are other requirements applicable to wearable smart glasses AR applications in the museum and art gallery context?

Wearable smart glasses AR user requirements are an important area for research due to the novelty factor of consumer devices and applications and the enormous potential for future

implementations (Chamberlin, 2014). Nevertheless, wearable AR user requirements have been relatively unexplored, with the majority of research still focusing on mobile AR (e.g. Gafni, 2008; Han et al., 2014). Consequently, there is currently a gap between the body of knowledge and practice in this area. Therefore, the identification of user requirements is critical for the successful implementation of wearable AR in museums and art galleries in the future.

Methods

Manchester Art Gallery wearable smart glasses AR Project

This study was conducted at Manchester Art Gallery as part of the wearable smart glasses AR Project which started in January 2014 in cooperation with Manchester Metropolitan University, Manchester Art Gallery and 33 Labs (Google Glass app developers from California, USA). The project aimed to enhance visitors' experience when visiting Manchester Art Gallery through the augmentation of information on paintings. Being one of the early academic projects in Europe to test wearable AR application in an Art Gallery environment, the test application aimed to identify user requirements. Figure 1 displays one example of information which visitors received while trying Google Glass at a painting within Manchester Art Gallery.

Please insert Figure 1 about here

Testing of wearable smart glasses AR Application

A wearable smart glasses AR application, using Google Glass as a testing device, was developed for Manchester Art Gallery and the test of the application took place on 10th and 11th of April 2014 at Manchester Art Gallery. A purposive quota sampling method was used to collect data and Table 2 presents the profile of the 28 participants. Purposive quota sampling is a non-probability sampling technique where the researcher selects participants based on certain characteristics (knowledge, gender, age etc.) (Daniel, 2011; Tongco, 2007). According to Tongco (2007), it is often used in preliminary studies where the feasibility of projects is assessed. Guest et al. (2006), revealed that purposive sampling is the most commonly used form of non- probabilistic sampling, and the size of sample relies on 'theoretical saturation' which is considered the point at which no new themes are observed in the data. According to Morse (1995), tests of adequacy of estimating the sample size required to reach saturation are not existent. In the case of the present study, participants were selected to cover a wide range of the target market which ranges from younger teens to visitors in their eighties. Half of the participants were recruited in the Art Gallery on the day of testing, while the other half of the participants was recruited through Manchester Art Gallery's Facebook, Twitter and webpage. Using this technique, the researchers aimed to get a wider spectrum of participants, from more tech-savvy (through social media) towards the general target market.

Please insert Table 2 around here

Just before starting the test of the application, basic functionalities were explained and demonstrated to participants, such as the swiping functions, voice command, taking pictures and sharing functions. In order to facilitate understanding, it was projected on a smartphone screen for the participant to follow. After this demonstration, participants were asked to use Google Glass to get familiar with the device. Afterwards the test moved on to experience the wearable AR application (Figure 2).

Please insert Figure 2 about here

Participants were asked to take a picture of the George Stubbs painting with the Google Glass and then to share it with the Museum Zoom application. Following these steps, the application provided participants with augmented information such as audio and text information (displayed as cards, the way Google Glass works) about the painting, the artist and related paintings. Afterwards, participants took part in a semi-structured interview which enquired about the overall opinion of their interaction with the application and Google Glass, functionalities, drawbacks, advantages and disadvantages as well as future expectations. Using this experiment approach followed by interviews is a useful way of gathering information on user requirements at the early stage of app development (Wilson, 2013), while the analysis, through an affinity diagram, facilitates problem definitions (Chandra, 1993). These problem definitions are essential to provide recommendations for future app development.

Data Analysis - The Affinity Diagram

The data were analyzed using an affinity diagram. Data analysis through affinity diagrams is a common analysis technique within the discipline of human-computer interaction (Jacko and Sears, 2003; Sharp et al., 2007). Using affinity diagrams allows a graphical representation of categories and constructs and is becoming a more and more popular way to analyze data as it enables a number of research experts to analyze the data at the same time. This reduces bias thus enhancing the reliability of findings (Babbar et al., 2002). In addition, Jacko and Sears (2003, p. 932) acknowledged that "affinity diagrams derive much of their value from the process that produces them (i.e., a deep engagement with the data combined with recurring reflections of the generalization that best captures a number of data elements)". According to Sharp et al. (2007), affinity diagrams aim to organize ideas within a hierarchical structure of categories, whereby categories are not predefined but emerge from the data using an inductive approach. After categorizing the data, these categories are then grouped in order to create a hierarchy of themes (Jacko and Sears, 2003). Figure 3 shows one of the two tables used for the creation of the affinity diagram.

Please insert Figure 3 about here

Findings

In this section, user requirements were analyzed and presented. The final affinity diagram resulted in five main user requirement themes which consist of a number of sub-themes.

Content requirements

The first research question of this study was: *What are the key content requirements applicable to wearable smart glasses AR applications in the museum and art gallery context?* Within the theme of content requirements, a number of sub-themes were identified including content quality, information accessibility and links to other paintings as well as personalized information.

Content quality

In terms of content quality, interviewees (P6, P7, P8, P16) hoped for in-depth information when using a wearable AR application. P22 suggested that the "benefits are for people who go to the gallery and want to get more kind of meaty information about the paintings". In addition, almost half of the participants (P1, P5, P8, P9, P10, P12, P13, P15, P18, P23, P26) revealed the importance of experiencing benefits. P1 pointed out the advantage of alternative and extended information when using wearable computing within art galleries and P10, P12 and P13 added that additional background information on paintings is an important aspect of application design. P28 acknowledged that in order to be used and accepted, the application has to offer better information than on the labels provided next to the paintings. In addition, P5 pointed out that the application should offer information that is easier to process in order to enhance understanding. Overall, participants agreed that the wearable AR application offers an opportunity to provide more information than is currently available in art galleries. The richness of the content was identified as another sub-theme of content quality (P1, P4, P5, P7, P8, P14, P15, P18, P23). P4 stated that it "gives so much information so easily" however, P14 counter-argued that there might be "an overload of information". Hence, for application design finding the right balance is inevitable.

Information accessibility

A number of participants revealed the importance of information accessibility. The ease of access, for instance, was considered by numerous participants (P5, P6, P8, P12, P18) as an important aspect of using wearable AR applications in art galleries. P6 found that accessing information on the wearable AR application is much easier than reading labels, especially when galleries are crowded and P12 pointed out "information is right at your disposal so you look at it". In addition, the idea that information appears automatically should be integrated into application design (P17, P23). P6 revealed that it would "be nice to have image recognitions [and it] automatically searches for information". Furthermore, the possibility for information retrieval should be incorporated in application design (P6, P25). P25 suggested that favorite paintings and the corresponding information should be bookmarked and P6 added that pictures taken within the gallery should be saved for later use. Finally, P9 and P23 liked the idea of using a wearable AR within the art gallery as it enabled them to receive instant information on demand without the inconvenience of having to look at up.

Links to other paintings

The idea to create links between paintings, in the same, and other galleries to navigate between paintings and receive recommendations, was considered a crucial success factor of a wearable AR application (P1, P2, P10, P14, P16, P18, P23, P27). For instance, P27 was interested in "the bit where you can cross reference [between paintings]… [and was] impressed with this experience". The thematic way of viewing paintings was appreciated by P14 and P18. P14 liked that you "can view the gallery thematically but not just by date" and according to P18 "it is exciting to look at one piece and other works of art turn up" as normally "galleries group paintings [and it is] interesting to find new connections through Google Glass". Based on this idea of creating links between paintings within the same gallery, five participants (P5, P13, P18, P20, P22) thought that the application should guide visitors through the gallery based on common themes. In addition, four participants (P4, P15, P18, P24) felt that the application should provide recommendations based on viewed paintings. The application should be designed using the "Amazon style, if you like this, you might also be interested in…" (P15). In addition,

according to P18, “the exciting thing is being able to link a particular piece of work with other works of art that aren’t in the same gallery” which shows the desire for a worldwide database of paintings accessible through a wearable AR application.

Personalized information

Finally, participants requested tailored and personalized tours to make their experience more individual (P5, P8, P10, P14, P20, P21). P20 stated that a “personalized tour would be interesting”. In addition, the choice to receive information was considered important by P9, P13 and P26. For instance, P26 asked for “a freedom of choice to look at what you want” which was supported by P9.

Function requirements

The second research question of this study was: *What are key function requirements applicable to wearable smart glasses AR applications in the museum and art gallery context?* With regards to function requirements, participants considered a variety of functionalities that were seen as crucial for the user benefit of the application. All listed functional elements were therefore allocated to common groups in the affinity diagram and were summarised into the following subheadings: social function, navigation, ease of use, and instructions for interaction with hardware and software.

Social function

As discussed in previous studies of mobile applications (Ferguson, 2008; Milano et al., 2010; Johnson et al., 2012) social functions were regarded as crucial for participants in order to spark and maintain their interest as well as enhance the spread of the application among museum and art gallery visitors. While social functions such as peer recommendations were seen to enhance the overall tourist experience (Johnson et al., 2012), the majority of interviewees referred to the incorporation of the basic sharing function in the application. Therefore, three subthemes were evident, general findings on sharing content within the application, sharing via third party links such as Twitter and Facebook and sharing functions that could be used within the Art Gallery environment.

The opinion with regards to sharing options was divided into participants who were interested and highly eager to share self-generated content with their friends and relatives (P1, P3, P15, P20, P24) and others who were not considering sharing information. Specific reasons for not being interested in sharing information were unclear, though some participants simply claimed to be inactive on social networks (P14, P15), as opposed to any privacy issues. As an alternative P26 recommended enabling sharing not only within Google circles, but open up the functionality to external social networks which had a wider reach, such as Twitter and Facebook, suggesting that “having the integration with your E-mail address, Facebook and Twitter is really good as it allows you to share straight away”. P10 and P16 on the other hand considered the alternative to share information with other visitors in the Art Gallery. According to P16, one way would be “when you come with a friend, maybe you can share between glasses” considering the use of wearable AR by other visitors in the Art Gallery.

Navigation

Another crucial function requirement in wearable AR application in Art Galleries was revealed to be navigation functions, as also discussed by Shi et al. (2010). The general idea was based around interactive maps where the visitor could orientate himself around the art gallery or museum. Using interactive maps, participants hoped to be able to navigate through the various galleries more quickly. P8 and P11 additionally recommended the use of maps in order to lead to certain paintings in the gallery, as a means of not simply locating a painting, but "showing the route to [other] paintings of interest".

Ease of use

In order to assure the functionality and utilisation of the application, P10, P14 and P24 claimed that user-friendliness was the key determinant for the adoption of wearable AR applications. Since this was the first time that most participants had experienced and interacted with wearable AR, it was observed that some were struggling with the menu and interaction methods of the device, although it was claimed to have been developed to use natural hand gestures (Funk et al., 2014). Findings revealed that the majority of participants found wearable AR easy to use. Some participants including P1 revealed that it should be more intuitive, but P24 mentioned, "it's user-friendly. Anyone who uses a smartphone will get used to it". A number of interviewees added on this note that the interaction through voice commands was regarded as more convenient (P6, P7, P11, P13, P15, P19) and P19 confirmed the preference for voice command "I didn't like the swiping. I would have liked everything done by voice command". By being able to use voice commands on certain functions, it was found that participants perceived wearable AR to be more convenient compared to smartphones, as it did not involve "having to take [the] phone out" (P19). The overall ease of using wearable AR was confirmed by P3 and P11 as "recording was so simple" (P3), since it did not require any further adjustments and "it's easy to use for older people since it doesn't have many buttons" (P11).

Instructions

While participants were generally quick to get used to interacting with the wearable AR application, it was pointed out that a brief introduction into the main functionalities of the application, in form of a tutorial or quick help guide, was considered helpful. In the interviews it was identified that interaction came naturally, and P22 added that most people are quite responsive to touch technology "so it seemed about a five minute or ten minute tutorial was fine". However, two participants (P10, P26) mentioned that such a support was only necessary in the beginning due to the novelty of the hardware as well as application. Therefore, providing an index that would show the overall menu to facilitate navigating through the application was suggested (P10, P26). For most participants, however, an introduction to the application was found to be sufficient to understand the functionalities of the application (P1, P5, P6, P11, P13, P16, P20).

Other Requirements: Experience, Resistance and Comfort

The final research question was*: What are other requirements applicable to wearable smart glasses AR applications in the museum and art gallery context?* From the data collected, we found requirements within three areas including experience, resistance and comfort.

Experience

In fact, user experience has been discussed as one of the main influential factors determining the value of a user technology (Tractinsky, 2006). Investigating the factor of experience as a user requirement, the following subthemes such as novelty, hedonic attributes, individual experience, usefulness and value and learning were identified.

Novelty

The novelty factor of the wearable AR application was a crucial determinant of participants' perception. Since it was the first time for the majority of participants to try wearable AR, it was observed that interviewees enjoyed the attention they received and stated they would like to "use it once due to its novelty factor" (P9). A number of participants further pointed out that the Art Gallery AR experience through wearable AR provided a "fresher" (P3, P27) and more "exciting" (P11, P27, P28) impact on the overall experience. P15 and P26 referred back to traditional audio guides and suggested wearable AR "replace audio guides" (P26) in the near future. With regards to the research outcomes, the novelty factor has been reflected on and will be considered with care, as it seemed to have a crucial impact on participants' opinions about the overall experience.

Hedonic attributes

The overall hedonic outcomes of the interviewees were very positive. While P4, P8 and P20 mentioned that it was "fun to use" (P8) due to the new experience that was generated, P27 "was surprised [to] like it because [P27] did not want to do it" on first sight. The interviews revealed that for some participants the way of projecting information and interacting with the device was unexpected but perceived as "enriching as it felt no information was missing" (P13) and information was "very useful" (P16). P13 and P19 were "excited and looking forward to become available" after the research.

Individual experience

On the one hand participants revealed that through using wearable AR to retrieve information, the visitor was able to receive more personalised information according to the user's interest (P14, P18), while P9 commented it was more personal due to the device being "out of everyone's way", as opposed to current mobile devices. P6, P9, P11, P14, and P27 pointed out that the use of wearable AR in the Art Gallery was beneficial for "people who come alone" as it provided an "uninterrupted experience" (P6) being able to pull the user out of reality into one's "own world" (P9, P27). On the contrary, it was perceived negatively for social interactions, as it would "isolate" (P10, P14) from others, making it more difficult to have social interactions within the art gallery. Therefore, it was identified that art galleries should restrict the use of technology in art galleries when visiting with other people (P12, P13, P14) due to the "issue of [maintaining] social etiquette" (P13). It was further said that wearable AR provided a platform that would encourage visitors to have a deeper engagement with the painting in art galleries through the additional information it could provide on demand (P4, P8, P12, P16, P20, P22, P27). However, participants argued that it was crucial to be in command of whether wearable AR was chosen to be used to retrieve information, as the interviews revealed that some participants were enjoying art without the intervention of technology. Therefore, P2, P8 and P27 suggested the use of wearable AR only to access desired information and then simply switching it off, or taking off the device in order to enjoy the art by itself.

Usefulness and value

The usefulness to the visitor in the art gallery was identified as the critical value for utilising Google Glass and the AR application. Therefore, it was suggested that time efficient information should be provided as a more convenient way of accessing information. P6 commented, "you don't have to search for information yourself", while P2 and P10 noted the practicality of the application saying, "it's really good to save going up and reading" (P2). The majority of participants, however, stated that the application was promising. Usefulness was argued around providing a different view of the actual art pieces. P27 stated in this regard, "I can think of other pieces of work I would like to look at with the knowledge, knowing that I can just stand and look". Doing so, the interviews revealed that participants were able to have a higher appreciation of the paintings due to the intuitive provision of additional information.

Learning

The learning experience was identified as an additional significant user requirement. It was found that participants were eager to access additional information on other paintings after trying out the application for the first time. P8 noted that it "gives a wider picture through information about the artist, painting and other works". A common opinion was formed around accessing desired information that would motivate the user to "dig deeper" (P14) and look for more information on paintings of interest. P9 and P11 on the other hand revealed that such applications had a significant potential to serve as a learning tool sparking the interest of visitors and was claimed to be more helpful to remembering information.

Resistance

In addition, resistance was found as another important part of user requirements for the development of wearable smart glasses AR applications in the museum and art gallery context. Within the theme of resistance, a number of sub-themes were identified including issues with the device, application, social acceptance, costs and distractions.

Device

The biggest problem was perceived as the screen. A number of participants felt that the screen was not big enough (P19, P23, P25) and that the resolution was too low (P6). However, it was felt that wearable AR provides a brighter and clearer picture than the original painting (P27) and another participant favoured the graphics (P12). Furthermore, P4 acknowledged that it "gives you more value looking at paintings". Nevertheless, blurriness was perceived as a negative aspect of the screen (P18). It "was slightly blurred and out of [P18] comfortable field of vision". In addition, the heating of the device (P9) and the short battery life (P24) were considered drawbacks. Similarly, seven participants had problem with the audio and felt it was too quiet (P1, P2, P6, P13, P20, P24). There were also issues in terms of design. P23, P10 and P19 found it "not very fashionable" (P23) and P11 and P20 identified that it was not designed for people with longer hair as it affected their capability to use the touch screen. P9 and P17 stated that people do not want to tap towards their head all the time as "it is inconvenient" (P17). A valid point was also made by P5 and P22 who criticized the way pictures are being taken "as you don't know what picture will actually come out". Finally, some participants had simply higher expectations, hoping for a "full AR experience" (P18), "something more advanced" (P19) and better hardware (P6, P23).

Application

Most participants criticized technical issues. The general feedback was that the application was clearly a prototype and in its infancy due to problems like crashing and being too slow. Therefore, the majority of participants agreed that these issues need to be overcome in order to ensure a smooth implementation and acceptance (P1, P3, P5, P6, P12, P13, P21). In addition, the issue of the limited content was identified by P1 and P18. However, it was acknowledged by both participants that the application was still a prototype and therefore minor problems are considered acceptable. Furthermore, P4 and P9 revealed that it was difficult to navigate through the application suggesting that the final application needs a clear structure and menu. Finally, some participants had higher expectations of using Google Glass and its AR capabilities. P23 pointed out "I don't like having a separate image that is then sort of in front of the picture, both should be brought together" which was supported by P18.

Social acceptance

Social acceptability was identified as one of the problems of using wearable AR (P1, P6). P1 revealed that users have to be aware that there are some people "who don't want to be part of it". In addition, privacy issues need to be considered (P6). Self-consciousness was another issue identified by numerous participants. Participants would be too frightened (P12, P27), self-conscious (P23) or simply "bothered by people starring" (P27), while others felt that it was good for self-conscious people due to limited human interaction (P14, P25). In addition, P4 and P16 suggested that it might be difficult for older people to use to use and thus, might be more attractive for certain market segments such as the youth and children's market.

Affordability

In terms of affordability, P4 and P22 revealed that if Google Glass was affordable they would use it straight away. Some participants found that these new technologies are too expensive (P3, P8, P10, P17) and "couldn't really justify spending £1,000". This leads to the problem of how art galleries could offer the service to its visitors, with options to either provide only the application or the devices. In addition, P5, P19 and P27 confirmed that "Google Glass should be available in the art gallery".

Distraction

Seven participants felt that wearable AR distracted from the art gallery experience and from the way they were appreciating paintings (P1, P4, P9, P12, P15, P19, P23). P19 and P23 go to art galleries to escape modern technology hence, feel that it is the wrong place to implement wearable AR. P15 was concerned that wearable AR influenced appreciation and so should be taken off when looking at paintings. On the contrary, P14 identified it is "easy to switch between screen and paintings" and P27 confirmed that "it is comfortable to look straight at painting when wearing Google Glass". Another issue was distraction for other people (P3, P5, p9, P10, P12, P19). P19 felt that the voice command might disturb people in the immediate vicinity, however P12 identified that the audio is useful as other people are not distracted. Interestingly, P9 and P10 were concerned that people might run into each other due to lack of concentration when using wearable AR.

Comfort

Finally, comfort was perceived as an important part of user requirements for the development of a wearable AR application in art galleries and another requirement applicable to wearable smart glasses AR applications in the museum and art gallery context.

Comfortability

A large number of participants were surprised by the unobtrusiveness of the device (P2, P5, P6, P8, P11, P13, P18, P27). P5 felt "if I wore it enough I would forget that I was wearing it" which was supported by P2. P6, P11 and P13 found it light and natural to wear the device. Half of the participants simply were astonished by the comfort of wearing it and P28 acknowledged that she was surprised that "it was not disturbing at all". In addition, P2 added that it was "neat and tidy". While P7 and P9 felt it "was a bit heavy" and "too clunky", numerous participants (P5, P6, P11, P12, P13, P28) agreed that Google Glass is "not heavy and comfortable" (P21). In terms of the comfort for the eye, P3, P7 and P23 criticised the screen. P7 for instance had a "strain in the eye when looking at it". In addition, P26 did not like the adjustment of the screen as it was a bit challenging to see the content. Interestingly, P13 found that the device can be used with glasses while P10 argued that they had to take off their normal glasses. P3 and P10 experienced dizziness and headaches after using Google Glass. Finally, numerous participants felt that Google Glass was imbalanced due its design (P1, P4, P6, P10, P19). For example, P22 felt "it felt a little uncomfortable and sort of lop sided" and P4 added "around the face it's a bit fumbly". This shows that there are divided opinions with regards to comfort suggesting that the current version would not be accepted by all markets.

Adaptability

In terms of adaptability, not all participants felt comfortable to use the wearable AR application (P16, P18, P20). "I don't know whether it is my own coordination but I was struggling" (P18). Others felt that it takes time to become familiar with the device and application (P6, P9, P13, P14, P27, P28). However, there were also three participants (P8, P21, P22), who "knew quickly how to interact with…" the device and application (P22). Overall, this shows that although Google Glass can be operated through minimal commands (wiping, tapping, voice), it is essential to provide participants with instructions on how to use it to minimize problems and dissatisfaction.

Table 3 summarizes all user requirements for a wearable AR application in the art gallery context.

Please insert Table 3 about here

Discussion and Conclusion

The aim of this research was to identify user requirements of a wearable smart glasses AR application in the museum and art gallery context. Previous mobile-related research identified content and function requirements as well as other requirements (e.g. Gafni, 2008; Herzwurm and Schockert, 2003; Pulli et al., 2007). The main contribution of this study is the identification of art gallery visitors' requirements in five categories, including content requirements and function requirements which confirms the mobile requirements literature. In addition, this study identified resistance, comfort and experience as user requirements specifically tailored to the

wearable AR art gallery context. Also, the affinity diagram revealed specific sub-themes of the requirements of wearable AR applications for museums and art galleries. According to Patrício et al. (2003), there is an increasing awareness and acceptance of the importance of user requirements for a successful implementation of applications. Therefore, in order to develop and implement a well-perceived wearable AR application, it is crucial to identify user requirements, as users will be the ones to accept or reject the application (Ginsburg, 2010).

The interviews have shown that the development of a wearable smart glasses AR application should strongly focus on **content requirements**. Overall, visitors require in-depth, rich, appropriate and additional information to experience the art gallery, which supports research by Kalay et al. (2008). In addition, it was found that content should be easily and instantly accessible, confirming research by Zheng and Pulli (2005). Further, the potential of a personalized art gallery experience was identified by numerous participants and Olsson et al. (2013) suggested AR capable devices be incorporated into next-generation tourist guides due to the potential of personalising information freely according to the user's interest. Interviewees confirmed that a wearable AR application should provide personalised tours and navigations based on interests, previously viewed paintings and connections between paintings. In fact, creating links between paintings was perceived as the strongest benefit of using wearable AR within art galleries, an idea that received only limited attention by previous literature.

In terms of **function requirements**, easy to understand instructions and manuals were considered inevitable for a seamless visitor experience due to the novelty factor which supports Gafni (2008) who acknowledged that software needs to be easy to understand. Ease of use was identified as another function requirement which correlates with the need of simplicity identified by numerous researchers (Gafni, 2008; Herzwurm and Schockert, 2003; Pulli et al., 2007; Tan et al., 1998; Zheng and Pulli, 2005). However, the design of Google Glass allows software developers to provide content with minimum interaction due to limited capabilities which might aid the participants' desire for simplicity. Furthermore, social functions were identified as immensely important and should be included in wearable AR art gallery applications in order to enable visitors to share their experience with a wider network, which confirms previous research (Ferguson, 2008; Johnson et al., 2012; Milano et al., 2010). Finally, in terms of function requirements, navigations and maps should be included to allow visitors to use wearable AR to guide their experience.

Regarding the **experience**, visitors enjoyed the novelty factor and felt wearable AR and the application to be innovative, fresh and exciting. The present study identified that wearable AR helps to add value to the experience through the enhancement and provision of additional information. Furthermore, it made the experience more enjoyable and interesting. The study found that this was particularly the case for individual visitors as it increases their level of interaction. In addition, Anderson et al. (2010) identified that interactive applications can help to enhance the learning outcomes, which was supported by participants. In fact, children in particular may benefit from using wearable AR as part of their learning activities. Further, the possibility to provide audio, video and visual content enables visitors to receive diverse information which adds value to their experience.

However, there were also some factors leading to **resistance**. Looking at Google Glass itself, some participants had higher expectations, were disappointed with the battery life and screen quality and size as well as the audio level. Some of these issues support findings by Glauser (2013) who reviewed Google Glass for medical purposes. In addition, participants were disappointed by the crashing and freezing of the application and device due to heating issues. Similarly, Pulli et al. (2007) found that there are often speed issues due to limited processing power, which is considered a drawback of AR applications. Patrício et al. (2003) also agreed that the speed of performance is an important user requirement for e-services. In addition, the application had technical issues and required more navigation and content. Furthermore, issues with regards to affordability and general costs were raised. Some participants felt distracted, while others perceived no distraction, however using these devices might distract others while using these new and innovative devices. Finally, privacy issues were identified and public acceptance came up as a resistance factor. Skiba (2014, p. 346) confirmed that "issues of privacy, security, confidentiality, and informed consent are underlying limitations" of wearable computing.

With regards to **comfort**, the literature argued that devices need to become more efficient and convenient for everyday life in order to assist time-pressured people to complete their daily tasks effectively (Pulli et al., 2007). This is particularly true for wearable devices such as Google Glass as the interviews confirmed that the device needs to have a natural feel to it in order to be fully accepted. Museum visitors want to quickly know how to interact with a device and application. In addition, physical comfort (e.g. no strained eyes and headaches) was pointed out as one of the main requirements and should be considered for full adoption.

Due to the novelty aspect of wearable computing and Google Glass in particular, there have been limited research attempts to examine user requirements for wearable AR applications. Nevertheless the identification of user requirements, according to Patrício et al. (2013), is immensely important to ensure successful implementation. Therefore, this study aimed to provide the foundation for wearable AR application development through the identification of user requirements in the context of an art gallery. Museums and art galleries can benefit from these findings as potential of wearable computing within these public organizations are demonstrated and also detailed user requirements for application design are provided. Overall, this study collected and disseminated information on new and advanced developments in the field of information systems by focusing on the relatively unexplored area of wearable AR user requirements.

Theoretical contributions

The aim of this paper was to identify user requirements of a wearable smart glasses AR application in the museum and art gallery context through the incorporation of visitor's point of view. Visitors are the people who actually determine the success of an implemented technology and therefore it was crucial to understand and investigate user requirements of this new and innovative Google Glass AR application (Patrício et al., 2003). Being among the first to investigate this technology in the art gallery context, this study added to the understanding of user requirements of a Google Glass AR application. While research is still investigating mobile AR user requirements (Han et al., 2014), the technology is quickly moving towards consumer versions of wearable AR. However, research focusing on wearable AR is still scarce. Although

the developers program of Google Glass was completed in 2015, a new and improved consumer version is expected to be released in near future. In particular, currently Google Glass focuses on niche markets including museums and galleries. Therefore, this present study provides an important foundation by being the first academic research to investigate user requirements for a wearable AR application in the art gallery context.

Theoretically, this study used the existing field of user requirement research and extended it to the wearable AR context. Therefore, the main theoretical contribution is the extension of exiting mobile user requirement research into the wearable smart glasses AR context. Furthermore, within this study, there are two elements of extensions of user requirements research. The present study added three key requirement themes including resistance, experience and comfort to the pool of wearable AR knowledge. In addition, previous user requirement research in the mobile context tends to focus on factors within content requirement and function requirement. This study identified sub- user requirements in the context of wearable AR, which were not identified in the mobile context. Finally, the mapping of user requirements can be used as a starting point for the identification of user requirements within different cultural heritage visitor attractions.

Practical implications

The present study suggests a number of key implications for wearable smart glasses AR applications in museum and art galleries. The first implication affects museum and art gallery practitioners and managers. The findings revealed that museum and art galleries have to focus on the provision of high quality content, instant and personalized information as well as links to other paintings. Further, if comfort issues are considered, the study revealed that art galleries should provide their visitors with a valuable, educational and enjoyable experience through the implementation of wearable smart glasses AR. This study provided a foundation for the development of new and cutting-edge applications within public organizations such as art galleries or museums and these findings can be used as a guideline to future investment of wearable AR in the art gallery context.

Secondly, there are implications for wearable smart glasses AR app developers. Function requirements need to be taken into consideration when developing and implementing wearable AR in art galleries. Applications have to be easy to understand and use as well as provide social and navigation functionalities. Furthermore, resistance factors should be taken into account and current problems with Google Glass and applications resolved in order to ensure a seamless experience. Findings revealed key requirements that have to be considered by management and applications developers in order to ensure a successful implementation of wearable AR. This gives important implications for which features should be implemented in applications and what needs to be avoided in order to ensure tourists' satisfaction.

Finally, this study offers important implications for other cultural heritage visitor attractions who may consider the implementation of a wearable AR application to complement the enhancement of the museum and art gallery visitor experience in the future. In addition, museums and art galleries are important institutions for spending quality time in and for lifelong learning for its visitors and local residents. This study added to the enhancement of visitors' and residents' quality of life through experiencing art and culture through new and innovative technologies such as wearable AR.

Limitations and future research

Nevertheless, this study had a number of limitations and recommendations for future research. First of all, the methodology was only based on qualitative interviews, which makes it difficult to generalize the findings to a wider population. However, it is believed that an exploratory approach is appropriate for this novel field of research that aims to investigate the unexplored area of wearable AR user requirements, where a user's point of view is particularly important to understand and implement. In order to confirm and potentially extend user requirements, conducting quantitative research with visitors in art galleries is therefore suggested. Using an affinity diagram enables researchers to collaboratively and reliably discuss and analyze research findings. With regards to our sample, recruiting tech-savvy respondents for this study can be considered an important limitation as general museum visitors that did not have an opportunity to participate in the study. In addition, the study was solely conducted at Manchester Art Gallery and thus, different research contexts might show different outcomes. Therefore, future research could use a similar methodology to identify user requirements in other art galleries, potentially extending the scope of study to other attractions or museums. Furthermore, these findings will help to develop fully functioning applications and future research can investigate the visitor and learning experience of using wearable AR in art galleries. Finally, future research could focus on a comparison of mobile AR and wearable AR user requirements within the art gallery context to identify the most appropriate approach to enhancing the visitor experience.

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Table 1. Augmented Reality User Requirements in the Mobile Computing Context

Classification	User Requirement	Description	Literature
Content Requirements	Information Quality	Information provided on the surrounding area should be relevant and up to date	Gafni, 2008; Karahasanović et al., 2009; Kenteris et al., 2009; Gebauer et al., 2010
	Accessibility	Easy and immediate access to content is required through enabling hardware and software	Zheng and Pulli, 2005
	Social Media	Software enabling link to social media platforms to overcome geographical boundaries and connect people	An et al., 2008
	Personalization	Content requires personalization to filter and tailor accessible information on private mobile devices	Gafni, 2008
	Usefulness	Devices and programs need to be add value and be beneficial for the user to encourage repeated use	Karahasanović et al., 2009; Gebauer et al., 2010; Dinh et al., 2013
Function Requirements	Simplicity	User interface design should be intuitive and easy to navigate	Gafni, 2008; Herzwurm and Schockert, 2003; Pulli et al., 2007; Tan et al., 1998; Zheng and Pulli, 2005
	Purposeful interface design	Software design needs to be purpose-driven	Gafni, 2008
	Speed	The processing speed and performance of the device influences user's decision to use repeatedly	Patrício et al., 2003
	Small software size	The size of the program needs to be small, as it impacts on the speed and performance	Herzwurm and Schockert, 2003
Other Requirements	Privacy & Security	Privacy policies need to be in place to assure user acceptance of new technology	Zheng and Pulli, 2005
	Entertainment	Mobile applications should be entertaining	Karahasanović et al., 2009
	Efficiency	Benefits include convenience and time-saving functionality	Pulli et al., 2007

Table 2. Profile of Participants

Participant	Gender	Age	Awareness of Google Glass	Technological innovativeness	Recruitment channel
P1	Male	30-39	Yes	Moderately	Art Gallery
P2	Female	Over 60	No	No	Art Gallery
P3	Female	Below 20	No	Moderately	Art Gallery
P4	Male	20-29	Yes	Moderately	Art Gallery
P5	Male	20-29	Yes	Moderately	Art Gallery
P6	Male	40-49	Yes	Moderately	Art Gallery
P7	Female	20-29	No	Moderately	Art Gallery
P8	Female	Over 60	Yes	Yes	Art Gallery
P9	Male	Below 20	Yes	Moderately	Art Gallery
P10	Female	20-29	Yes	Yes	Art Gallery
P11	Female	Below 20	No	No	Art Gallery
P12	Female	Below 20	No	Moderately	Art Gallery
P13	Male	50-59	Yes	Moderately	Social Media
P14	Female	20-29	Yes	Moderately	Social Media
P15	Male	20-29	Yes	Yes	Social Media
P16	Female	20-29	Yes	Yes	Social Media
P17	Male	40-49	Yes	Yes	Social Media
P18	Male	30-39	No	No	Social Media
P19	Male	30-39	Yes	Yes	Social Media
P20	Female	30-39	Yes	Yes	Social Media
P21	Female	30-39	Yes	Moderately	Social Media
P22	Male	20-29	No	Yes	Social Media
P23	Male	20-29	Yes	Yes	Social Media
P24	Male	20-29	Yes	Yes	Social Media
P25	Male	30-39	Yes	Yes	Social Media
P26	Female	20-29	Yes	Moderately	Social Media
P27	Female	50-59	Yes	No	Art Gallery
P28	Female	60 and above	No	No	Art Gallery

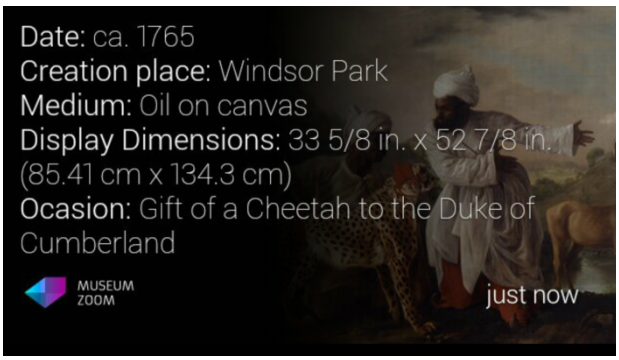

Figure 1. Google Glass Art Gallery Test Application

Figure 2. A participant experiencing the Google Glass AR application

Figure 3. Affinity Diagram

Table 3. Summary of user requirements

User requirements	Summary of themes
Content requirements	
Content quality	Visitors require, in depth, rich, appropriate and additional Information.
Information accessibility	Information should be easily and instantly accessible, ideally turn up automatically in background, saving and bookmarking for easy retrieval of content should be enables
Links to other paintings	Application should provide additional information on related paintings in the same gallery and external galleries, guide to related paintings and make recommendations based on viewed paintings
Personalized information	Visitors should have a choice what to view based on their preferences, get personalized tours and information
Function requirements	
Instructions	Tutorial, manual or introduction is needed to understand the device and its functionalities, and menu should be included to provide overview
Ease of Use	Simplicity, control, intuition, convenience and user-friendliness
Social	Sharing functions, social media sharing, peer recommendations, between-device sharing
Navigation	Directions and maps should be included
Experience	
Novelty	Wearable AR application is innovative, fresh, exciting and bring attention
Usefulness/Value	Participants perceived it as useful, valuable, helpful. Using wearable AR saves time and helps appreciate the paintings.
Hedonic	Experience perceived as enlightening, enjoyable, exciting, surprising and fun
Individual experience	It helps engaging with art in a new way, positive for individual visitors and user empowerment however, isolates
Learning	Positive for children, motivates to learn, helps remembering and understanding, is a technological tool for learning, provides additional information however, can create a negative influence
Multimedia	Provides opportunities to get audio, video and text
Resistance	
Device	Higher expectations than actual experience, disappointed with battery-life, audio level, screen size and adjustments and overall design
Application	Higher expectations than actual experience, technical issues, navigation and more content is missing
Affordability	Affordability and price are an issue, should be provided complimentary
Distraction	(Not) feeling distracted from appreciating paintings, distracting other people
Social acceptance	Privacy is problematic, people are (not) self-conscious, public acceptance and might only be appropriate for certain target markets
Comfort	
Comfort	Positive and negative opinions regarding comfort, some considered it unobtrusive, comfortable; others had problems with the weight, sight, dizziness and imbalance
Adaptability	Some found it easy to adopt, some needed time to get used to it and for some it felt difficult