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Augmenting cultural experience : Evaluating the use of augmented reality technology to enhance the visitor experience at a historic site

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Abstract
Recently, museums and historic sites have begun reaching out beyond their traditional audience groups, using more innovative digital display technology to find and attract a new audience. Virtual, mixed, and augmented reality technologies are becoming more ubiquitous in our society and "virtual history" exhibits are starting to be available to the public. The authors have undertaken multiple experiments at a historic fort in upstate New York, evaluating digital display technology used by site visitors. The paper also contains a discussion of the potential benefits and problems of designing interactive virtual museum/heritage displays, based on standard usability guidelines.

Key words: Cultural Heritage, Augmented Reality, User Experience, Human Computer Interaction, Evaluation, Fort Ontario.

Introduction

Recently, museums and historic sites have begun reaching out beyond their traditional audience groups, using more innovative digital display technology to find and attract new visitors. Virtual, mixed and Augmented Reality (AR) technologies are becoming more ubiquitous in our society and "virtual history"

exhibits are starting to be available to the public. While phrases such as "bringing history to life" are commonly applied to AR technology used in these contexts, the standard practice of juxtaposing physical artifacts or objects with virtual imagery may not always function as intended, or express the meanings intended by the media creators.

This paper will introduce research that has investigated the use of a range of AR technology in cultural heritage application areas. This paper will describe the results f multiple experiments undertaken at a historic fort in upstate New York, to assess the effect of display technology on site visitors

Research Objectives

This study is guided by the following research objectives:

1. To investigate usability factors associated with the use of AR applications in cultural heritage sites.
2. To identify issues with the visitor experience when information is transferred using AR application
3. To propose future strategies for the application of AR applications in cultural heritage sites.

Hypotheses

H01: There will be no significant usability issues with AR applications in a cultural heritage setting.
H02: Visitors will be able to garner significantly more information, than through traditional means.
H03: The AR applications will provide an engaging and enhanced experience for the visitor.

Literature Review

Mobile devices can be used to provide contextual information about historic sites, such as historical views of structures, details of past events, or insights into how people lived. Augmented Reality (AR) and/or Virtual Reality (VR) technology provides a relatively new, and efficient, mode for communicating historical information to visitors to a cultural site (Iavancic et al, 2013).

Augmenting the Tourist Experience

Over the last few decades, the use of AR and VR has become increasingly popular within the tourism sector, as an attempt to introduce more immersive experiences for visitors (Yung and Khoo-Lattimore, 2019). Since the majority of modern travellers own a smartphone, this is a simple, yet effective, way to enhance the visitor experience (Han et al., 2018). AR technology can provide significantly more information to the tourist, than if only visual aids (signage) were used (Yung and Khoo-Lattimore, 2019).

Moreover, a mobile AR application, being highly portable, can function as a tourist guide that delivers relevant information upon request, thus minimizing information overload and irrelevant information (Kounavis, et al., 2012). AR applications can allow tourists to experience simulations of historical events, places, and objects by rendering them in real time over their view of the real world (mediated through a smartphone screen). These AR systems can also present text, video, audio, features of interest, and even relevant comments from previous visitors (Tomiuc, 2014).

Multiple studies have demonstrated an overall positive effect on the visitor experience when utilising AR applications. Furthermore, research also suggests that there may be a significant differences in AR satisfaction based on whether or not the user (tourist) is more willing to take risks and engage in exploration, and the willingness to try new products and experiences (Jung et al., 2016; Yung and Khoo-Lattimore, 2019; Yung and Khoo-Lattimore, 2019).

With the ability to augment a user's real-world surroundings, AR has been considered to have significant potential for the tourism industry as a value-added enhancement. The use of AR devices has the potential to create the next generation of computer tourist guide (Han et al., 2018).

Augmenting the Cultural Heritage Experience

There is a general feeling among the cultural heritage community that AR can add value to existing historical experiences, allowing visitors to explore unfamiliar environments in an enjoyable and exciting way (Tscheu and Buhalis, 2016). Experience with these systems in cultural heritage sites all over the world

has repeatedly demonstrated that AR visualisations can provide additional insights when applied in cultural heritage settings (Damala et al., 2008; Yung and Khoo-Lattimore, 2019).

AR technologies create a new visitor experience that is very different from traditional print media or audio. For historical sites this means that visitors no longer need to rely on audio guides, pamphlets, posters, or signs, they can experience the same information through an interactive and engaging medium (Gjøsæter, 2014).

'Heritage Tourism' is a rapidly growing tourism sector. Heritage tourism is largely fueled by its economic benefits, however cultural heritage tourism also produces many other benefits, such as rekindling traditional arts and crafts, revitalizing cultures through reviving dying customs, and increasing demand for local arts, leading to a preservation of culture (Cranmer and Jung, 2014). The expansion of the internet allowed tourists to plan individual experiences when visiting cultural heritage sites(Han et al, 2018).

Augmenting the Museum Experience

An early form of technology used to augment the visitor experience was the audio guide. From early cassette tapes to digital systems, these audio devices experienced widespread use in museums around the world. Some modern versions include location sensing technology or RFID tags, to ensure relevant audio in played as the visitor approaches each exhibit (Edwards, 2013).

Recently, there has been a shift from audio augmentation to visual (multimedia) augmentation using AR technologies in museums. Museums have repeatedly reported increased engagement with these more immersive and interactive experiences. Most museums believe that the visitor experience is enhanced by giving patrons access to information that is far beyond the current display panels and exhibits (Johnson et al, 2012)

For the museum, an AR approach can allow visitors to interact with displayed objects in an intuitive way. Museums also provide a broad experimental user base, with visitors coming from a range of backgrounds with varied demographics (Dalama et al., 2008).

Researching the Augmented Experience

A number of researchers are assessing the application of AR systems in situated experiential learning in cultural heritage settings. Many of these projects aim to understand the variables influencing engagement with these AR applications versus fixed media stations/displays and to identify the arrangement of variables that produce the most optimal learning outcomes, and the best experience for the visitor.

Jung et al. (2016) hypothesised that social presence would have a positive impact on education experience, aesthetic experience, entertainment experience, and escape experience. Additionally, they proposed that education experience, aesthetic experience, entertainment experience, and escape experience would all have a positive impact on visitor experience. Participants used an AR application at the Museum in Cornwall, UK as well as a Samsung Gear VR application. At the end of the experiment, the researchers found that social presence had a strong influence on all four experiences. It was also found that education, entertainment, and escape experience were found to have an impact on visitor experience. This work demonstrated that, in the context of social presence, mixed reality technologies can have a significant positive effect on the overall visitor experience for people at museums and other cultural heritage sites (Jung et al, 2016).

Jung and Dieck (2016) used interviews to carry out a mobile AR project at Manchester Jewish Museum in the UK. The interviews identified a number of key benefits of AR technology (Jung and Dieck, 2016):

- Improves the interest of multiple demographics in visiting museums.
- Has the capability for the preservation of knowledge, history, historic buildings, and memories for future generations.
- Significantly increases the intention to return to the museum.
- Significantly increases the intention to spread positive word-of-mouth information.
- Allows visitors to gather in-depth information by themselves.

- Brings exhibits to life and for people to explore in more details.
- Improves the teaching and learning experience

Vaart and Damala (2015) investigated a mainly text based and object focused AR system at the Allard Pierson Museum in Amsterdam, Holland to explore the potential of affordable but meaningful in-house AR content for smaller or medium museums (Vaart and Damala, 2015; Damala et al, 2019). The data gathered in this experiment showed that the participants were positive about the technology and that it added value to the museum visit. Responses from participants seemed to indicate that text could be a suitable alternative high-quality visual content for AR tools, but when asked about the most memorable parts of the experience was, the responses all involved animation or sound clip (Vaart and Damala, 2015; Damala et al, 2008).

Fort Ontario, New York

Fort Ontario is a historic American fort situated in the City of Oswego in Oswego County, New York. It is administered by the NYS Office of Parks, Recreation and Historic Preservation and operated as Fort Ontario State Historic Site. Fort Ontario is located on the east side of the mouth of the Oswego River on high ground overlooking Lake Ontario (Figure 1).

Figure 1: *Fort Ontario, Oswego, New York*

Fort Ontario is one of several forts erected by the British to protect the mouth of the Oswego River and water route to NYC. The original Fort Ontario was erected in 1755, during the French and Indian War in order to bolster defenses already in place at Fort Oswego on the opposite side of the river. At that time it was also known as the "Fort of the Six Nations," but the fort was destroyed by French forces during the Battle of Fort Oswego in 1756 and rebuilt by British forces in 1759 (Bell, 2017)

During World War II, Fort Ontario was home to approximately 1000 Jewish refugees, from August 1944 to February 1946. The Fort Ontario Emergency Refugee Shelter was the only attempt by the United States to shelter Jewish refugees during the war (Bell 2017).

The restored fort is open to the public as a state historic site. It was listed on the National Register of Historic Places in 1970 (NRIS, 2010).

Augmenting Fort Ontario

In a similar manner to the AR system and applications described in the previous sections, the authors developed a number of AR systems at the Fort Ontario historic site in Oswego, New York. The Fort Ontario AR applications are intended to allow visitors to reconstruct historic artifacts within the historic site without actually physically interfering with the space or the artifacts itself.

The AR application development had a focus on the quality of the content as well as personalized content. Based on previous research this should enhance the experience that visitors have at Fort Ontario, and it should increase the interest levels of visitors in history and location. The aim is to generate a higher rated visitor experience and increase recommendations from visitors to new visitors, leading to higher visitor traffic for the site.

Interactive AR technologies create a new user experience different than print media or audio. For historical sites this means visitors will no longer need to solely rely on audio guides, pamphlets, posters or signs, they can experience learning the same information through a new, interactive medium.

The ability to successfully implement a mobile AR system at Fort Ontario is dependent on the user's ability to learn how to use the AR technology. Mobile Augmented Reality (MAR) applications have specific features that affect the user's ability to efficiently and successfully utilise the technology. MAR applications can also present multiple potential usability issues such as knowledge of the target users and their experience with using technology, glitches within the application (freezing or not recognizing artifacts), compatibility issues among some mobile phone types, and individual user visual/ perceptual differences. Understanding the context in which the AR technology is being used at Fort Ontario can help eliminate user frustrations and the misinterpretation of information.

The research in the following sections of this paper describes work undertaken by the authors to investigate these issues, by running a series of experiments, using visitors to the Fort Ontario historic site as experimental participants. This work stands apart from much of the previous work examining the use of AR systems at cultural heritage sites as it takes a distinctly User Experience (UX) approach to the technology, focusing on the perceived usability of the AR systems.

Experiment 1

The main objective of this preliminary investigation was to investigate usability issues associated with the use of the AR application 'Aurasma' for an Android smartphone and to study the effect the use of the AR application has on visitors at the historic site of Fort Ontario

Using images and text provided by staff from Fort Ontario, a series of short historical slideshow videos were created. These videos were attached to images of specific points of interest (i.e. buildings or landscapes) at the Fort, these images acted as triggers for the slideshows. Visitors used a cellphone and pointed the camera at objects/building of interest in the fort, if a trigger image for a point of interest was recognized by the AR application, then a historical slideshow video with information about that specific point of interest would play automatically on the smartphone.

Participants

The participants for this study consisted of 22 randomly selected visitors of Fort Ontario in Oswego, New York. All participants were aged 18 years and above, and of mixed gender. Informed consent was obtained from all participants prior to the study.

Materials

To ensure consistency, each participant used the same Samsung Galaxy Note 3 smartphone to perform this study with the AR application Aurasma pre-installed on the phone. A pre-experiment questionnaire was administered to gather demographic and background information. A self-report, post-experiment questionnaire was also given to collect the user's experience with the AR application.

Aurasma is a free AR application for iOS or Android mobile devices, which uses digital overlays of 3D environments to create a heightened and interactive experience for users. A user can hold their device up to an image, building, location, or scene and AR application will recognize the static image and automatically play an overlaid video. Software on the phone tracks an image on the screen and replaces said image with a video (Edwards, 2013).

The AR application provides the user with more information according to the user's context. By hovering over a building or artifact, the handheld device could serve as a personalized tour guide. This provides users with the potential to customize their tour, get information relevant to their personal interests and enhance their experience through the use of multimedia.

Design

A descriptive research design was used to explore the applicability and usability issues of the AR application in a historic site environment using smartphones. The time taken for task completion along with the self-reported ease of use, satisfaction, comparative browsing information and user preferences for future implementation were used as the dependent variables.

Procedure

After obtaining the informed consent, each participant was asked to complete a pre-experiment questionnaire. Participants were then provided with the smartphone and asked to hover the phone in front of any one of the five points of interest until the AR application recognised it. Once the point of interest was recognized, a video with the information about the point of interest played automatically on the phone. The participants were asked to perform cognitive walkthroughs, expressing their thoughts throughout the experiment. (Rizzo et al, 1997) A post-experiment questionnaire was provided after the task. The factors that were observed by the researchers during each experiment are listed in Table 1.

Table 1:

Factors observed during each experiment

Total task completion time
Time taken for recognition
Initial device orientation (landscape/portrait)
Orientation adjustments
Final device orientation (landscape/portrait)
Number of AR experiences completed
Observed body language with the device
Observed facial expressions

Results

The demographics survey illustrated that the participant pool consisted of a varied age group out of which 86% already owned a smartphone and 82% of participants had previously visited historic sites.

The observed data from the experiment was analysed to identify any usability issues based on the factors listed in Table 1. All 22 participants (100%) successfully completed all the AR application tasks. The average time taken by the device to recognise the point of interest was 2.9 seconds. All 22 participants

(100%) started with portrait orientation, only 2 participants (9%) changed the device orientation to landscape.

The body language while using the application was observed as natural in 19 participants (86%) and unnatural in 3 participants (14%). Two participants (9%) were observed to be excited by the AR application, 12 (55%) were happy and 4 (18%) normal during the experiment. Most of the participants (91%) reported that it felt natural to hold the device in front of the point of interest.

On difficulty level experienced throughout the experiment, 15 participants (68%) reported that it was very easy, 6 participants (27%) reported that it was easy and only 1 participant (5%) reported that the task was of normal difficulty. On the speed of recognition of point of interest, 11 participants (50%) reported that it was very fast, 10 participants (45%) reported that it was fast and 1 participant (5%) reported that it was slow.

On reporting whether more information was delivered by the AR application than by traditional means, 7 participants (32%) reported that they strongly agreed, 10 participants (46%) reported that they agreed, 2 participants (9%) reported that they disagreed, 2 participants (9%) reported that they didn't know, and 1 participant (5%) strongly disagreed. When participants were asked about future implementation of AR applications inside the fort, 13 participants (59%) reported that they strongly agree and 8 participants (41%) reported that they agree.

The surveyed data was also analysed to identify any usability issues associated with the MAR application, as used in a historic site environment. Such usability issues were evaluated in terms of self-reported ease of use, satisfaction, recognition speed, learning new information, preference for indoor implementation and preference over conventional guide. The data was based on a five-point scale ranging from most negative to most positive. Table 2 demonstrates the median value of all the dependent variables.

Table 2:
The results of the descriptive survey

	Ease of use	Satisfaction	Recognition speed	Learning new information	Preference to implement inside the fort	Preference over conventional guide
N	22	22	22	22	22	22
Median	5.00	4.00	4.50	4.00	5.00	4.00

A Wilcoxon Signed-ranks test was performed for all the variables to test each of their significance against a test median of 4.5. It indicated that at 0.05 level, ease of use (p=0.162), satisfaction (p=0.061), recognition speed (p=0.841) and preference for indoor implementation (p=.394) was not significantly different than the tested median (Mdn = 4.5).

Similarly, another Wilcoxon Signed-rank test was performed for the remaining variables against a test median of 4. It indicated that at 0.05 level, learning new information (p=0.742) and preference over conventional guide (p=0.062) was not significantly different than the tested median (Mdn = 4).

Discussion

This preliminary study provided significant results regarding the lack of any noteworthy usability issues in the use of the AR application at Fort Ontario. The very high significant median value of 4.5 (in a range of 1 to 5) in ease of use, satisfaction, quick response time and preference for indoor implementation illustrates the highly positive interest among visitors towards the use of this immersive technology. The significant median of 4 in learning new information and preference over conventional guides clearly shows an acceptance of such technology for contextual information delivery and personalised tours.

While the effectiveness of the application was clearly evident, the efficiency of use was measured using both quantitative and qualitative parameters (object recognition time and the recognition speed experienced by the participants). Both parameters reported rapid response times, which contributed to the participant's feeling that the application was easy to use. The satisfaction level of the participants with the AR application was measured through both observed facial expression during the experiment and self-reported level of satisfaction after the experiment, both reported extremely high positive values.

The use of portrait orientation by all 22 participants (100%) as initial orientation was an interesting and unexpected result, only 2 participants (9%) changed the device orientation to landscape. This result demonstrates that many visitors may prefer the portrait orientation to the landscape orientation. This can be related to the fact that holding the device in a landscape form for a longer period of time with one hand can be both physically challenging and unnatural for many users (Kuhlmann et al, 2020).

The results of this preliminary study clearly indicate that the use of immersive AR applications on smartphones for cultural heritage visitors has a high potential to provide a rich media content experience and contextual information delivery. From a human-computer interaction standpoint, these results provide valuable insight into future possible AR applications at historical sites.

Experiment 2

The aim of this particular experiment was to investigate the use of an AR app to augment the self-guided tour booklet used by visitors to Fort Ontario. A professional AR application was built using an AR software package called 'Artivive' designed to give users a more immersive historical experience.

The self-guided tour was rebuilt as an AR experience using high resolution modern pictures of the original mapped areas in the booklet. The project integrated photos and video from the 1860s all the way to a recent wedding on the fort grounds. As the visitor approaches a building or location pictured in the tour booklet, they point their smartphone at the matching photo and the AR application plays a slideshow of images, showing how the building or location has changed through the years (Figure 2).

The aim of this particular experiment was to undertake smaller, more detailed, experiment that investigated the user experience of using a higher fidelity AR application.

Participants

The participants for the study were recruited on-site at Fort Ontario and were New York State Employees from Fort Ontario State Park. There was a total of 5 participants (3 males, 2 female), with an average age of 54.6 (SD = 15.44), took part in the study.

Materials

All participants were instructed to use their smartphone to download the Artivive application from either the Google Play Store or Apple Store. Artivive is an AR tool that works in a similar manner to the Aurasama application used in experiment 1, by linking images to videos or slideshows. (Artivive, 2019).

The Artivive AR tool was originally developed to be used in art galleries, allowing artists and curators to augment works of art by adding animated features, or historical and contextual information to individual works. The Artivive application is now widely used in museums and galleries around the world, and it's use has extended into other application areas such as cultural heritage and historical sites. In most cases, visitors use their own smartphones or tablets in order to experience the augmented experience (Artivive, 2019).

The Fort Ontario self-guided AR tour booklet is a laminate flipbook that has 24 different locations to explore throughout the Fort Ontario historic site. The AR application was developed a in a number of stages, including both low-fidelity and high-fidelity prototypes, and a final product that was designed to be used by visitors to the fort (SUNY Oswego, 2019). The Artivive AR tool was specifically chosen for this application as it provides a reliable, robust, fast, and scalable infrastructure and architecture.

When visitors use the self-guided AR tour booklet, the first page contains instructions how to download the Artivive AR application to their smartphone and how to use the AR application on the images

in the booklet. There is also a picture-map of the Fort with numbered labels, showing which image corresponds to which point within the Fort Ontario walls (SUNY Oswego, 2019. As a result, visitors using the Fort Ontario self-guided AR tour booklet, MAR application can personalise their visit at Fort Ontario (Kounavis et al., 2014).

Design

This study used a within-subjects design with one condition, with the independent variable being the Fort-Ontario self-guided AR tour. In this study, it was essential to run a within-subjects design so that each participant was able to experience the same AR tour and amount of walking from point to point on the mapped locations on the tour guide. The dependent variable was an open-ended scale structure to assess the usability of the MAR application and visitor experience.

Procedure

The cognitive walkthrough is a task-based inspection method widely adopted in evaluating user interfaces (Rizzo et al., 1997). The rigorous use of a cognitive walkthrough allows user experience researchers to better understand how a high-fidelity prototype interface is working throughout a development process. Results from the cognitive walkthrough evaluation of the AR application being used with the Fort Ontario self-guided tour booklet distinguished differences between usability attributes and allowed the developers to plan for the implementations of the product at Fort Ontario.

Figure 2: *The AR app being used on the tour booklet at Fort Ontario*

To gather user data on the high-fidelity prototype of the AR application, a cognitive walkthrough was conducted on the first four sites of interest in the Fort Ontario self-guided tour booklet. The user testing was of a smaller scale than the previous experiments.

The experimental participants were given brief instructions regarding the tasks they were to complete for the cognitive walkthrough. These tasks included downloading the Artivive application to their personal devices, visiting the first four sites in the self-guided tour booklet and using the AR application at each site. It was important to observe the participants with minimal intervention, to obtain data that mimicked the real visitor experience with the technology.

After completed the tasks, the participants were handed a short open-ended usability survey to complete based upon the tasks they completed to also asked rate their overall visitor user experience, and then were debriefed upon finishing the survey. While the users were completing the tasks, the experimenter took down notes from the user's feedback on the application.

Results

The demographics of the participant population in this experiment was significantly older than the demographics of the general visitor population. However, the use of such a population for this experiment did demonstrate that older visitors would not only use the AR application, but be positive and accepting of the technology. The experimental participants reported that 80% of them had not used an AR technology before. However, all of the participants (100%) expressed a wish to continue to use the technology in the future.

The detailed cognitive walkthroughs highlighted a number of specific usability problems with the AR system. A proportion of the participants (60%) reported issues with downloading the AR application due to lack on internet speed or not wanting to use satellite internet to download an application. This issue has since been resolved by the installation of local wi-fi at Fort Ontario that is available to visitors.

A proportion of the participants (60%) reported issues using the AR application due to the weather. It was noted that the self-guided tour booklet becomes awkward to use outdoors in rainy or windy weather – unfortunately, the AR developers do not have a lot of control over the weather at the fort.

A small proportion of the participants (20%) reported that it was difficult to hold the booklet and phone for long periods of time. The developers made sure that the multimedia presentations on the AR application were short and succinct.

However, even given these reported issues, all of the participants (100%) stated that the instructions given in the self-guided tour booklet were simple and easy to understand.

Discussion

The aim for this study was to see if using AR technology could enhance visitor experience at a historic site. Other studies have suggested that technology may play a problematic role when used by older users, and older adults tend to complain about difficulties with using new user interfaces (Tacken et al., 2005). It is important to notice that data from the Fort Ontario cognitive walkthrough suggest that the AR technology application not only enhanced the older users experience, they found it simple and effective to use.

This experimental study was limited by the small sample size of the participant pool. This limitation was due to the fact that each user test took a significant amount of time and required the collection of a large of amount of data from the cognitive walkthroughs. Future experiments should use a larger participant pool and increase the number of variables and metrics measured during the experiment.

The principal focus of this experiment was the assessment of a high-fidelity prototype to provide feedback for the development of an AR application that would be used at Fort Ontario. This system is now implemented and being used regularly by visitors to Fort Ontario.

Experiment 3

Research Design

The Officers' Quarters One building at the Fort Ontario State Historic Site had at one point been fully furnished with artifacts intended to emulate their original historic state when it was in active use from around the late 1860s. The loss of climate control within the building resulted in the removal of all the artifacts and furniture to prevent any damage and losses. This project aimed to restore the rooms in some capacity to what they were and allow the public the chance to view the building in its past furnished state.

The success of the previous AR systems at Fort Ontario led to the belief that utilising augmented reality could be a cost-effective solution to allow visitors to gain an insight into the history of this building. An AR application would allow visitors to view the building and rooms as they were intended to be viewed.

Figure 3: *Officers' quarters 1 at Fort Ontario*

This AR application was developed using Google's ARCore SDK. In a similar manner to the previous two applications, the MAR works by collecting feature points from images that are stored in a database and upon recognizing a specific image, it overlays a historical image of what the furnished officers' quarters room used to look like, over it. A group of experimental participants were then observed using the AR Application in the officers' quarters building of the historic site. A range of user experience data was collected to allow an assessment of the usability of the AR application.

Participants

The participant pool for this study consisted of 11 users, the pool was predominantly made up of students from the State University of New York at Oswego. The participants ages ranged from 18-28 years of age.

Materials

The AR application was developed in Android Studio and utilises Google ARCore to handle the augmented reality functionality. It is designed to overlay images on top of other ones and is intended to show visitors what the rooms in the officers' quarters building at Fort Ontario used to look like fully furnished with antique furniture around the late 1860s. ARCore, also known as Google Play Services for AR, is a software development kit developed by Google that allows for the rapid development of AR applications (Lanham, 2018; Nowacki and Woda, 2019).

This project used survey instruments to collect user experience data from the participants:

- The *System Usability Scale (SUS)* is a ten-question standardised survey that measures the efficiency of usability to a system. Participants are asked to score ten items ranging from 1 (strongly disagree) to 5 (strongly agree). Based upon results and calculation of the System Usability Scale, a score of greater than 68% would be considered an above average system, and anything scoring below 68% would be considered a below average system. The System Usability Scale is an efficient, reliable, well-tested way to analyse the AR application and determine whether changes need to be made to the system for future use.
- An *AR Survey Questionnaire* was provided to each participant. The first set of questions pertains to the usability and reliability of AR applications in historical spaces, and rates the system from 1 (Strongly Disagree) to 5 (Strongly Agree). The next section rates the users' previous knowledge of AR and historical spaces from 1 (Very Bad) to 5 (Very good). The final section of the questionnaire contains open ended questions pertaining to the participants history using AR and a few demographic questions for scalability purposes.

Design

This experiment utilised a within-subjects design, the experiments were conducted with one condition, with the independent variable being the Fort Ontario AR application. The application was designed for specific rooms in the Officers' Quarters building at Fort Ontario, and participants were undertaking specific tasks using the AR application interface. The dependent variable was the visitor user experience and the usability of the AR application, which was measured using the System Usability Scale (SUS) and the AR Survey Questionnaire.

Procedure

During this experiment, the participants participated in a guided cognitive walkthrough procedure. At the start of the experiment, each participant was given an informed consent form. Following this, they will be given brief instructions of the tasks they were to complete for the study and a short tutorial on how to use the AR application.

Participants were then tasked with moving between several rooms in the officers' quarters building and using the application on various images displayed in the rooms. After this, they will be asked to complete the two questionnaires and then debriefed.

Results

An analysis of the usability of the developed AR application was undertaken using the SUS survey data. The average overall SUS score was 84.8. The lowest was 70 and the maximum was 97.5 (Figure 4). Every participant rated the application at least a 70 making it, at its lowest rated, slightly above average or at least "good." Overall, the application would be almost "excellent" falling short by under 1 point (84.8 vs 85.5) (Bangor et al, 2009).

Some of the participants made specific feature requests such as being able to manipulate the image when it is displayed on the screen or having the image remain present on the screen after the initial recognition and augmentation. Currently, when a user scans an image, the new one is overlaid directly on top of the recognized image and stays anchored in place allowing the visitor to view the historical image.

A proposed alternative design, incorporating user feedback from this experiment, could use the images as markers to instead display the historical image on the smartphone as a persistent object that can then be taken around with them and even manipulated.

In the open-ended questions, all of the participants found the application to be simple to use and found the whole scenario to be very interesting.

The results of the AR oriented survey show that on average, participants tended to lean towards agreement with the given statements, and hence have a favourable impression of the AR application (Figures 5 and 6). A score of 2 or lower (indicating disagreement with the questionnaire statement) was only given on 5 occurrences across all 11 participants and 10 questions.

The first statement (I plan to use augmented reality applied to historical sites in the future) was ranked slightly lower than the average score. While still rating as an overall positive score, this slightly lower score may not necessarily be a negative result, as the participant not planning to use such systems in the future may have little to do with their impressions of the technology itself.

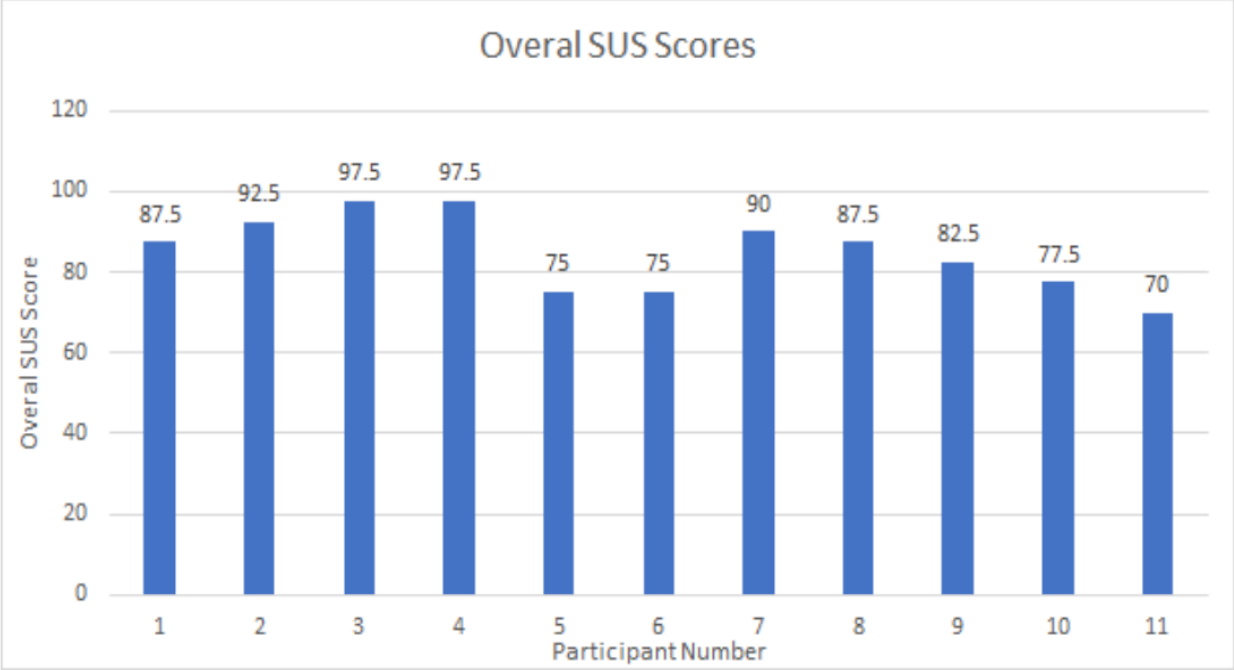

Figure 4: *Overall scores from the System Usability Scale (SUS)*

Figure 5: *The AR questionnaire results*

The third statement (I'd like to feel sensations) and fourth statement (I'd like to listen to sounds) from Figure 5 were also rated slightly lower than the average score. Again, while still rating as an overall positive score, this slightly lower score this may not necessarily be a negative result, as the participants may be indicating that the images provided enough information and context for the application to be a success.

The final statement (AR helped me get more information about the historical object) is also slightly lower than the average response (Figure 5). Again, the answer to this question still rates as an overall positive score, the slightly lower score was due to one participant answering this question with a negative response (Figure 6).

Statement	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11
Using augmented reality helped me get more information about the historical object.	4	4	5	4	3	5	4	3	3	4	3
Using augmented reality increased my visitor experience at a historical location.	5	5	5	5	4	5	5	4	2	4	4
I thought the system was easy to use.	5	5	5	5	5	5	5	5	5	4	4
I have the resources necessary to use augmented reality (e.g. smartphone).	5	4	5	5	5	5	5	5	5	5	4
Using augmented reality in historical spaces can be fun.	5	5	5	5	3	5	5	5	3	4	4
Augmented reality applied to historical spaces may be reliable.	5	4	5	5	4	5	5	4	4	4	4
In addition to seeing virtual images with augmented reality, I would like to listen to sounds related to the historical space.	4	4	4	5	1	5	5	5	5	4	2
In addition to seeing virtual images with augmented reality, I would like to feel sensations (e.g. temperature) related to the historical space.	3	3	3	5	1	5	3	5	5	4	4
With augmented reality, I will be able to explore historical places in a way that wouldn't be possible without it.	3	4	4	5	4	5	5	5	5	4	4
I plan to use augmented reality applied to historical sites in the future.	4	5	5	5	2	5	5	4	3	3	4

Figure 6: *Raw data from the AR questionnaire results*

Discussion

Analysis of the data from this experiment demonstrated that once again, that participants users enjoyed using the AR application in this historical context and that it enhanced their visitor experience at Fort Ontario. The data also illustrated that the AR application was overall, regarded to be very usable with every participant rating it to be at least above average on a usability scale.

This experiment utilized a marker-based AR implementation on an android smartphone, in which the AR System relies on an image recognition technique that uses the smartphone camera to identify visual markers, such as a QR or 2D codes. This then displays an AR overlay, typically a video or slideshow, when the key image is sensed by the software (Nayyar et al., 2018).

The AR application developed for this experiment was made using Google ARCore, which is only applicable to Android devices. It utilized the Google ARCoreimg tool to extract feature points from images

and then build a database consisting of those feature points. Those feature points in the database are what ARCore uses to perform the image recognition (Lanham, 2018; Nowacki and Woda, 2019).

With the ARCoreimg tool it is possible to test key images used by the AR application, and give them a score from 0 to 100 based on the clarity of the feature points and assigning a quality score for image recognition. It is important to try to avoid using images with sparse or repetitive features since the detection algorithms are based on points of high contrast. In most cases, a very low score (below 5) may not be enough to allow the database to build properly and thus the image recognition and the AR application will fail (Lanham, 2018).

This was a major issue during the development of this AR Application. The reference photographs that were used as markers for the AR application were images of empty rooms in the officers' building. Unfortunately, these images mostly consisted of large featureless spaces which resulted in many of them being unusable due to them being allocated a low image recognition score.

Many attempts were made to try to improve the quality score in a positive direction for those low scoring images. The images ere manipulated through the application of various color filters, brightness adjustment, contrast adjustment, or even adding colored borders around the images. Small improvements in image score were gained, however none of these adjustments had a significant effect with the highest quality score among all the images being about 35.

In future, rather than trying to affect the scores with image manipulation, it would potentially be more beneficial to manipulate the actual scene in the viewfinder of the camera. This would involve ensuring that objects are present in the shot rather than just blank walls. This could also potentially open up the possibility for a much wider range of images to be used with the AR application.

This experiment once again demonstrated the potential of AR applications to be a useful tool for cultural heritage sites to show content to visitors that they may otherwise be unable to do display. The portability of the MAR applications allows visitors to carry a technological tour guide around with them in their pocket. This opens up many potential new ways to interact with the history of a cultural heritage site, enhancing the visitor experience and increasing interests in the history of the site.

Conclusions

All three experiments demonstrated that the implementation of AR applications adds value to the historic site and the visitor experience. This supports multiple previous studies, which have repeated shown the benefits of AR applications (Cranmer et al, 2016; Yung and Khoo-Lattimore, 2019).

The user testing that was undertaken helped gather information for future developmental prototypes for AR applications in self-guided cultural heritage systems. Furthermore, the participant data and responses indicated that the AR applications described in this paper were successful in bringing the history of the fort to life. The participant's strong interest in cultural and historical value, demonstrated that AR can be considered an ideal tool to help cultural heritage sites bring history and culture to a life (Chiabai et al., 2013; Gervautz and Schmalstieg, 2012).

Overall, the experiments showed that AR created operational value for the fort. In addition, socially, these AR applications can increase positive word-of-mouth exchanges, which in turn can lead to increases in visitor numbers (Gordon et al, 2015; Jiang and Kim, 2015). The insight from the experiments undertaken at Fort Ontario has broader relevance for the cultural heritage sector. It is hoped that this work will encourage other sites to experiment with AR applications (Brown, 2005).

Usability data on the use of AR systems in the cultural heritage sector is limited. There are many dimensions when evaluating the use of AR systems and research is required within different academic disciplines to support existing theories and explore context-specific applications. (Yung and Khoo-Lattimore, 2019).

The design and development of any AR application needs careful planning and preparation. to. Previous research has illustrated how insufficient specification can lead to frustrated visitors due to the misalignment of usability features (Han et al., 2018). Therefore, site managers and application developers

can benefit from the findings of this, and other similar, papers that report on empirical results collected from user testing.

These applications were built as part of an agreement between the State University of New York and the Fort Ontario historic site. A working AR application is now installed at the fort and used regularly by visitors to the site.

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