AN EVALUATION OF THE USE OF AUDIO GUIDANCE IN AUGMENTED REALITY SYSTEMS IMPLEMENTED AT SITES OF CULTURAL HERITAGE

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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 (AR) technologies are becoming more ubiquitous in our society and "virtual history" exhibits are starting to be available to the public. There are numerous studies focusing on AR, however a scant amount of research is being done at historical sites. An initial experiment used repeated measures (ANOVA) to compare and rank three different types of AR devices used at a site of cultural heritage. A further experiment was then undertaken to observe participants using two different AR devices with and without sound to determine if which device used or the presence of sound impact the usability of the device, or the user's satisfaction/preference of specific devices. Several surveys, including demographic and usability surveys, were provided in order to collect a range of user data. A two-way repeated measures (ANOVA) were used to analyze the quantitative data gathered. No significant effects were observed based on the quantitative data provided by the surveys, indicating that all devices were equally usable and satisfactory, and that sound did not have a significant impact in this instance. However, the qualitative data indicated that users may prefer using AR technology on a smartphone device and preferred to use this device paired with sound.

KEYWORDS

Augmented Reality, Audio Guide, Cultural Heritage, Human Computer Interaction (HCI), Usability

1. 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.

Most personal mobile devices are now capable of combining the worlds of the virtual and the real. A range of AR technology has been changing how the users of these devices view the world, and more devices are constantly being developed. Using a mobile device, a pair of enhanced glasses, or a headset, a user can have their field of view integrated with virtual elements in real time. In the past, AR systems such as the Google Glass have been reported to have failed to make a significant impact on society [1]. However, research has shown that many current studies lack information on market factors, which in turn impacts the reported success of AR headwear. The current situation is that AR is having a significant impact in many fields, such as gaming, education, entertainment, healthcare, and even historical sites [2].

AR 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 [3, 4].

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 of multiple experiments undertaken at a historic fort in upstate New York, to assess the effect of AR technology (in particular the use of audio) on visitors to the historic site.

2. AUGMENTED REALITY

In recent years, AR has become an emerging disruptive technology, or a device that greatly alters how consumers function with technology.

AR technology is available in multiple formats. Head Mounted Displays (HMDs) commonly include video overlay on a non-transparent display, or video overlay on a transparent display [5]. Modern HMDs for use with an AR display are often the size and shape of sunglasses, with a small device on one of the lenses to project images. Many of these devices allow the user to issue voice commands to control the device, allowing users to check social media updates, time, make calls/texts, take pictures, and even show Google Maps [6].

Handheld displays are also used for AR, the most common of these being the ubiquitous smartphone. Handheld AR utilises the smartphone's built-in camera to provide augmentations as a window for AR to overlay real world objects. From Pokémon Go, to Mario Kart Live: Home Circuit, the entertainment industry has pushed handheld AR devices into the consumer arena. In these games users can drive AR cars around their living room on their Nintendo Switch or even catch Pokemon as they walk around the city streets [7].

Due to the current COVID-19 pandemic, AR has been identified as a major tool that will have a significant impact in a range of important fields [8]. For example, in educational environments, AR can also provide an immersive learning experience for those who are practicing distance learning, or it can be used to create animated books to engage learners [9, 10]. AR has also already made a major contribution to the health industry, where it's being used to simulate surgery for prospective doctors [11, 12].

2.1. History of Augmented Reality (AR)

The term "Augmented Reality" came from Tom Caudell and David Mizell in their early writing on head mounted displays [13]. These researchers showed that AR can provide some advantages over the more widespread Virtual Reality (VR) displays. These advantages include a reduction in price, since there isn't a need for as much processing power to create the digital images in the headset displays [14].

Early examples of AR relied on purely visual displays. In 1995, researchers added audio to an AR display for the first time. This prototype AR display used both audio and visual elements to act as a early version of an AR tour guide within a museum. The main disadvantage at the time was that the audio would play in a loop, rather than skip to relevant audio that the user needed [15].

One of the first full definitions of AR appears in 1997, where AR is described as bringing virtual, digital elements into the real world, interacting in real time, and displayed in three dimensions. At the time researchers also highlighted that there was a large gap in development in AR compared to more extensive work on VR system [16].

Around the same time, AR would move from being stationary to mobile. The first portable AR system, developed in 1997, consisted of a wearable AR backpack which allowed a user to move around and interact with digital objects located in the real world. This early device had several problems, which included a hard to read display and lack of precision in the tracking. Despite these issues, the first mobile AR test system was regarded as a significant advancement in the field [17].

Multi-user platforms have played a significant role in AR history. One of the first collaborative creations involved an AR system in which two users can interact and play games [18]. Other collaborative applications included education tools, for example a system where learners collaborate on mathematical geometry problems. Although experimental work demonstrated that these systems reduced the learning curve for the students involved, hand-eye coordination due to imprecise tracking was often still an issue [19].

Research involving cell phones as AR devices didn’t start until the beginning of the 21st century. Pioneering work from a number of researchers highlighted the importance of phones in the future of AR [20, 21]. Most of the early work involved marker-based AR, where the optical camera on the cell phone was used to optically track markers in the real world and generate digital content render in 3D at that location. This work led to design guidelines for future applications of AR, specifically the many smartphone AR apps that exist today [20,21].

2.2. Benefits of Augmented Reality

In modern times, AR has seen widespread implementation in a range of application areas. AR technology has moved from backpacks and heavy head mounted displays, to glasses and smartphones.

AR technology has also allowed users to express themselves in new ways. A recent study examined creativity, narrative skill, and story length of young subjects. It was observed that the experimental group, using AR, had better scores on every variable tested. This shows the benefit of not only technology, but more specifically AR for expressive purpose [22]. There have also been a number of interesting discoveries surrounding the creative design process. Research findings have shown a relationship between creativity and learning, where a wide range of learners felt that AR was easier to use [23].

Emotion is also be influenced by AR technology. One study on emotional intelligence found that AR could make subjects more active and therefore create a better sense of emotional wellbeing. This research used Pokemon Go, an application that rewards users for being active [24]. While not every AR technology will provide this, it’s good to note they have the ability to push users to be emotionally and physically sound. Another study focused on the role emotions play when using AR in learning exercises. This research demonstrated that positive emotions can be supported when learning and can help to provide a basis for making learning enjoyable [25].

Recent advancements within the field of AR technology have also shown benefits for those who need therapy, for example, providing a basis for the treatment of animal phobia or claustrophobia. The researchers found that those who scored well on the Behavioral Avoidance Test (BAT) benefited from AR phobia treatment. While both VR and AR aversion therapy treatments weren't as effective as current in-person practices, the technique shows great benefits in its application [26, 27]. Another interesting study on phantom limb pain found AR technology to be a very valuable tool to assist those missing limbs. Not only did the AR treatment provide significant pain release, but it also aided in lessening the amount of pain felt by subjects [28]

The marketing field has also become interested in AR, recently testing AR as a tool for marketing research. When subjects used AR applications, the overall attitude toward a brand remained positive. Other findings include that brand attitude is often associated with the quality of the virtual content [29].

Online services have also applied AR methods to increase market share. Studies of AR based online services have demonstrated that with AR technology, decision making is improved, it outperformed other modeling methods, users felt comfortable, and better personalization was provided [30].

3. PREVIOUS WORK AUGMENTING THE VISITOR 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 [31]. Since the majority of modern travellers own a smartphone, this is a simple, yet effective, way to enhance the visitor experience [32]. AR technology can provide significantly more information to the tourist, than if only visual aids (signage) were used [31].

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 [33]. 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 [34].

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 difference 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 [31, 35]. 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 [32].

3.1. Early Augmentation in Museums

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 is played as the visitor approaches each exhibit [36].

Recently, there has been a shift from audio augmentation (personal audio guides) 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 [37].

Over 30 years ago, head mounted devices were proposed as a way to present a virtual museum to the user. It was envisaged that the usage of such a system would allow users to move throughout the virtual museum in a similar manner to how they would move through a physical museum [38].

This theoretical type of virtual museum was patented in 2009. The VR system described in this patent details the specifics of a VR system that could be used in museums, connecting virtual representations of pieces of art to data sets that would inform the users of specific pieces of information (text, video, audio, etc.) associated with each piece of artwork [39].

3.2. Benefits of Augmentation in Museums

For the museum, an AR approach can allow visitors to interact with displayed objects in an intuitive, hands-on, personalised way [40]. Museums also provide a broad experimental user base, with visitors coming from a range of backgrounds with varied demographics [41].

Studies have demonstrated that using AR technology to enhance user interaction, providing sound/video to augment the standard images and visual displays in museums, can entertain and interest users, while maintaining a low cost entry threshold for museums with restricted budgets [42].

The integration of audio, video, text, pop up screens, accessed through AR technology, can also enhance the user's learning. The technology effectively allows users to access several different learning styles and approaches, combining the virtual with the physical [43].

Other research has shown that users found it easier to view and understand artworks in a physical museum when using smartphone-based AR technology. In particular, users reported that they had accessed more information about the exhibits compared to an audio tour. This study demonstrated that using a mobile AR system allowed the users to selectively access information about specific parts of the artwork that they had questions about. Whereas this task was deemed more difficult to complete using an audio tour [44].

One of the main perceived benefits of AR systems in museum settings is the increase in the user's interest in the museum exhibits. Studies have shown that in addition to being an efficient method of transferring information about a piece of art, AR can be used to make the exhibits feel more interactive. AR systems often allow the user to feel as if they were metaphorically stepping within the artwork or exhibit [45].

Studies which have focused on the use of AR enabled smart glasses within a museum for visitor use have found that though these glasses are a major advancement, the technology still not ready for full adoption. Users reported that they are comfortable with this form of technology and enjoy using them. However, smart glasses are still a relatively new technology and still do not quite provide a seamless blend of virtual and real-world elements. Although, most users agree that smart AR glasses technology has great potential for future applications [46, 47].

4. CULTURAL HERITAGE

Historical sites exist all over the United States, with a total of just over 2,600 locations [48]. These locations are maintained as a place of learning about the history of the United States. Tourists and visitors are able to learn about artifacts, architecture, and buildings of the local area. In the past, learning at these sites was often in the form of booklets, maps, and even oral explanations delivered by tour guides. These traditional dissemination methods have been shown to have the potential to disinterest visitors [49]. Multimedia media tour guides, often involving AR technology, are being introduced in many sites as a solution to improve visitor engagement.

4.1. Fort Ontario

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).

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 [50].

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 [50].
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 [51].

Figure 1. Fort Ontario, Oswego, New York

4.2. Augmenting Cultural Heritage Sites

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 [52]. 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 [31, 41].

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 [53].

'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 [54]. The expansion of the internet allowed tourists to plan individual experiences when visiting cultural heritage sites [32].

4.3. Previous Work Augmenting Fort Ontario

In a similar manner to the AR systems and applications described in the previous sections, a number of AR systems have been developed and tested at the Fort Ontario historic site in Oswego, New York (Figure 2). Developed in partnership between the State University of New York and Fort Ontario, these 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 [3].

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 increase the interest levels of visitors in history and location. The aim was to generate a higher rated visitor experience and increase recommendations from visitors to new visitors, leading to higher visitor traffic for the site.

The results of the preliminary experiments with AR technology undertaken at Fort Ontario has been previously published. 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 [3].

Figure 2. An AR Application Being Used at Fort Ontario

5. EXPERIMENT 1

The purpose of this study is to observe AR devices for use at historical sites. In understanding a user's reactions to different device types, historical sites can better educate, engage, and immerse their community about their past. There are several key aspects this study aims to understand, which first includes comprehending which values users are looking for in an AR device. Secondly this study looks to highlight which elements an AR device would need to be useful at a historical site. Through implementing three different AR devices with the use of media from Fort Ontario State Historic Site, these observations were made possible.

5.1. Participants

Due to the COVID-19 epidemic, and the resulting quarantines, isolations, and social distancing guidelines that were to be observed in order to ensure public safety, the experimental procedure had to take these restrictions into account. This produced a limited grouping in which allowed subjects to participate in the experimental sessions within a safe environment.

There were six participants in this experiment, with the age range being from 18 to 59. The minimum education was an Associates Degree, the highest being a Master's Degree, and majority had a Bachelor's Degree. The participants in this study also had a varying level of visual acuity, ranging from non-perfect vision to naturally perfect vision.

5.2. Materials

The materials required to perform this experiment were limited, but each experimental setup was complex. Three different devices were tested:

Smartphone**:** The first device was a mobile phone, that was used in unison with Artivive, an AR application that can animate pictures and art [3]. This application was used to show parts of Fort Ontario State Historic Site as they looked in the 18th and 19th century compared to how they look today.

Vuzix Blade**:** The second device used was a Vuzix Blade AR headset. This device allowed the user to see through the transparent lens while also projecting an image onto the lens of the glasses. This enables the user to see both the real world that is physically in front of them and digital imagery being projected onto the lens at the same time. The Vuzix Blade can be used with a smartphone which acts as a remote control. The Vuzix Blade is not compatible with the Artivive application, small videos of historical views were provided.

AR Glasses**:** The third device was a set of AR Glasses, these consisted of a plastic frame, a strap that wraps around the back of the user's head, and an insertion of piece of plastic that utilizes a mirror effect. A phone was placed into the frame, facing the mirrored plastic, allowing whatever is being displayed on the screen of the phone to be viewed by the user in a semi-translucent visor via the mirrored plastic. In this experimental setup, the mobile device will be displaying a slideshow of images and videos for the subjects to view, obtained from the Artivive application.

For all of these experimental setups, a common source of information was being displayed to the subjects. The information was orientated around a self guided tour of parts of Fort Ontario, that combined pictures, videos, slideshows, and visual information about the historic site.

5.3. Measurements

In order to understand the differences between each device being tested, a one-way, within-subjects, Analysis of Variance (ANOVA) was conducted. The analysis was undertaken using SPSS Statistical software. Measurements were taken from a questionnaire and exit survey, which included both qualitative and quantitative data. The questionnaire, named the Post-Study System Usability Questionnaire (PSSUQ) was adapted to fit the AR devices being used in this study [55]. This form of data collection and analysis allowed the comparison of different types of AR devices to one another. The exit survey was created to understand how well these AR devices would function and be received at Fort Ontario State Historic Site. The exit survey consisted of 15 questions, with four being in the form of a likert scale, and two multiple choice. The rest were open-ended in order to better understand the perspectives of subjects. In every case that a Likert scale was used, a lower number indicated a higher satisfaction score.

5.4. Procedures

All experimental participants were provided with information regarding the purpose of the research and a quick overview of the actions they will be undertaking. Some basic, anonymous, demographic information was collected.

All participants subjects started with the smartphone based Artivive system, in order to set up a baseline for the experiment. A self guided tour booklet with information on Fort Ontario State Historic Site as well as information on the interactive Artivive system was provided.

The second and third experimental tasks (Vuzix Blade or AR Glasses) were selected randomly. The subjects then repeated the tour with each specific AR device. After using each experimental AR device participants completed a questionnaire. At the end of the experiment, the exit survey was conducted.

5.5. Results

A one way repeated measures ANOVA was conducted to compare the subject’s satisfaction when using the three different AR devices. Results showed a significant effect of the specific device on the subject's satisfaction [$F(2,10)= 17.437$, $p= 0.003$].

A Tukey’s Honestly Significant Difference (HSD) test showed that the subject’s satisfaction when using the mobile device had a significantly lower mean than the subject’s satisfaction when using the AR Glasses ($p=0.12$) and that the subject’s satisfaction when using the Vuzix Blade had a significantly lower mean than the subject's satisfaction when using the AR Glasses ($p=0.03$). The subject’s satisfaction when using the mobile device did not differ significantly from the subject's satisfaction when using the Vuzix Blade (see Figure 3).

A trend that occurred in the qualitative aspect of the gathering of the results was the mention of the need of a different controlling function for the Vuzix Blade. Many subjects mentioned issues with understanding how to use the touchscreen that is built into to the device. Participants noted that the device would be easier to use if it had an external controlling device, or could be controlled via verbal commands/verbal confirmation. Additionally, subjects indicated that they would enjoy the Vuzix Blade much more if the functions of the mobile device were present in the Vuzix Blade. Primarily, participants stated that the Vuzix Blade was a device that had a lot of potential, but that their familiarity with mobile devicesmade this modality easier to use.

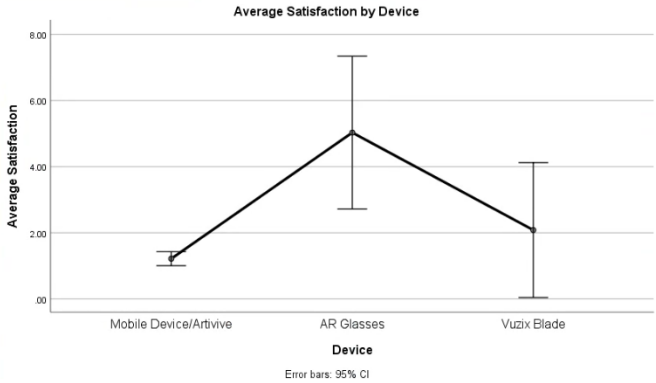

Figure 3. Chart of Average Satisfaction by Device

5.6. Discussion

This research is some of the first UX focused work undertaken to examine the use of AR devices at historical sites. While retention of information was not measured durinf this experiment, all subjects claimed AR would be useful to improve learning at historical sites. From both quantitative and qualitative data gathered it is clear that the mobile phone, and Vuzix Blade were the most enjoyed modalities. This is likely partially due to the fact that the AR Glasses were more difficult to control while maintaining focus on the material.

Factors surrounding previous failures in AR may have also been demonstrated in this experiment. Qualitative data showed that while the Vuzix Blade was a unique and innovative experience, it wasn’t as easy to use as the mobile phone. Additionally, several participants highlighted the fact that the lack of additional information was an issue. These could relate to previous findings in marketing applications of AR, where problems were identified due to the lack of common features with which the participants were already familiar [47].

It must be noted that both the mobile device and the Vuzix Blade scored extremely well on the assessed usability scale. Therefore, not only did the subjects not have significant problems with the mobile device or the Vuzix blade, but that they enjoyed using those devices for the purpose of AR historical learning. This expresses that subjects are excited to continue using this type of technology, at least in historical settings, but perhaps also in other ways.

Due to the statistically different satisfaction levels between the devices it's clear that there is a future for AR technology, if it is designed properly and easy to use. Ample evidence shows a preference toward devices with on-board controls, such as the mobile phone and the touch-bar of the Vuzix Blade.

The exit survey served as a gauge for understanding the needs of the user group, both with AR technology in general and in the specific setting of an educational historical site. The information gathered indicated that the primary concern with the Vuzix Blade was the hurdle of understanding how to control the device. Mentions of the use of an external controlling device or an audio controlled device indicated that the subjects felt as though they did not know what effects their actions would have on the device. This state of unpredictability seemingly made the device less appealing to them. Additionally, the subjects made notes of the wish that the Vuzix Blade had functionality that was more similar to the functions of the mobile device, such as not requiring a specific command in order to begin the picture effects.

Participants also registered a desire to have the Vuzix Blade interact more directly with the environment, by sensing the image that was in front of it and playing the corresponding video in a way similar to Artivive. This shows that the subjects wanted the device to be able to interact with the world and to be able to function on its own, without requiring them to initiate every command.

The last concern with the Vuzix Blade was that the device sometimes required subjects to not use personal eyeglasses with the device because of a lack of comfort or fear of their personal eyeglasses breaking. This indicates that while the functions of the Vuzix Blade are overall accepted and enjoyed, the design of the device itself needs to be adapted in order to make it more usable by individuals with visual impairments.

Interestingly, a number of participants mentioned that they would like the AR functionality tied into their personal eyeglasses. Many of the subjects indicated that if the options that were presented to them via a headset or mobile application were accessible in their everyday clothing/equipment, they would be much more likely to take advantage of the technology.
It should be noted that the majority of the issues indicated in the qualitative section of this analysis focused on the Vuzix Blade device, many times comparing it to the functions and usability of the mobile device. It is suspected that this is not because the Vuzix Blade is significantly worse than the mobile device, but simply because the Vuzix Blade has similar functions as the mobile device. Participants saw these two modalities as similar and were able to discuss the differences.

It is also predicted that there is little mention of the AR Glasses during this section of the exit survey not because users did not have complaints about the AR Glasses, but instead that the AR Glasses were often disregarded by the subjects as a viable device for this task.

6. EXPERIMENT 2

Due to the COVID-19 pandemic many historical sites are unavailable to the public. In this experiment attention was focused on the use of audio integrated with AR devices at historical sites. This experiment allowed the observation of a range of audio media combined with AR devices to provide guidance on how to improve a remote user experience. In order to analyse this, measurements on satisfaction, usability, and qualitative information provided by participants was collected.

6.1. Participants

Due to COVID-19, social distancing and safety guidelines were observed and of the utmost importance for this project, to insure the wellbeing of participants. Due to this restriction a limited sample size was used in order to better keep track of the devices and make sure that they are cleaned properly between participants.

This study had seven participants between the ages of 18 and 45. Five of the seven participants had used the Vuzix Blade and Artivive on a mobile phone in the previous study. The minimum education level was a High School diploma, and the most advanced was a Master’s Degree. There was also a divergent amount of visual acuity with three out of seven of the participants having some amount of defective vision.

6.2. Materials

A limited amount of equipment was needed to perform this experiment. This included two AR devices (a smartphone and a Vuzix Blade AR headset), as well as a workbook, and a set of videos (both with and without sound).

This experiment relied on users interacting with media that showed parts of the Fort Ontario State Historic Site as it looked in the 18th and 19th century compared to how it looks today. Each photo or video was provided with a description, either verbally or through text. The experiment also utilised the Fort Ontarion self-guided tour to orientate the users around places of interest at Fort Ontario.

6.3. Measurements

A two-way repeated measures Analysis of Variance or ANOVA was generated to understand the differences between subject responses. In order to do this SPSS statistical software was used.
The questionnaires used in this experiment were again derived from the Post Post-Study System Usability Questionnaire (PSSUQ) that was modified for AR device assessment [55]. There were a total of 20 questions designed to show preferences between devices with and without audio. An exit survey was also utilized, containing 15 questions, both in the form of a likert scale and open ended questions.

6.4. Procedure

At the beginning of the study, all participants signed an informed consent form which included a brief description of the study they were about to undertake. Some basic demographic information was then collected.

Devices were assigned to each participant in a random order, either Vuzix Blade or mobile phone in order to decrease confounding factors.

Depending on the device there was a different experimental introduction. Participants were either told how to use the Vuzix Blade and use it’s touch bar, or with the mobile device, they were shown how to use the Artivive application. After beginning the study, users were asked to spend five minutes exploring the information about Fort Ontario using each device.

6.5. Procedure

A two way within-subjects ANOVA was conducted to compare the subject’s satisfaction when using the different AR devices with sound and without sound. Results showed no significant effect of the specific device on the subject's satisfaction [$p > 0.05$]. However, the quantitative and qualitative data provided still offers a significant amount of information to be analyzed, despite not being statistically significant.

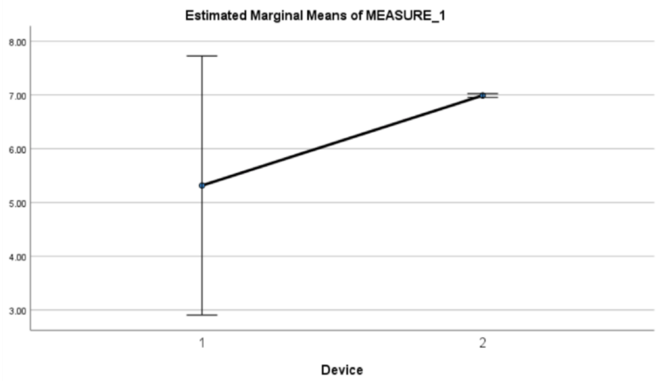

Figure 4. Responses to the Different Devices.

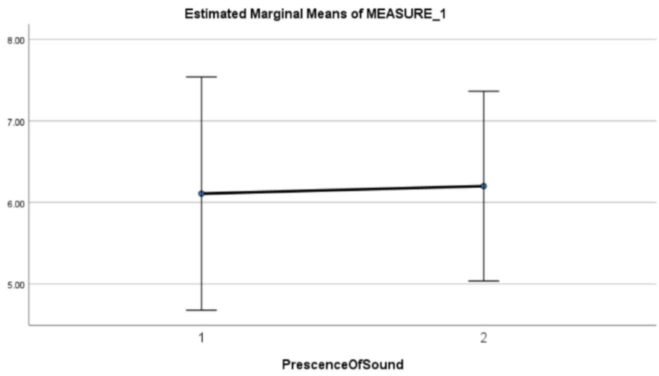

Figure 5. Measures of Satisfaction (Presence of Sound).

In the graph shown in Figure 1, Device 1 represents Vuzix Blade and Device 2 represents the phone. This illustrates the difference in the responses to the devices, showing that participants gave the phone (2) higher scores overall than they gave the Vuzix Blade (1).

As is observable, the satisfaction with the device increased when the phone was being used rather than when the Vuzix Blade was being used, however that was not a statistically significant increase.

Figure 2 illustrates that there was no significant difference between participant's scores for usability and satisfaction when using devices with sound or devices without sound.

Presence of Sound 1 represents the scores provided for the tasks in which sounds were not used, and the Presence of Sound 2 represents the scores for the tasks that were performed with sound. As can be seen, there is very little difference between the two scores, however both scores rate very highly for user satisfaction.

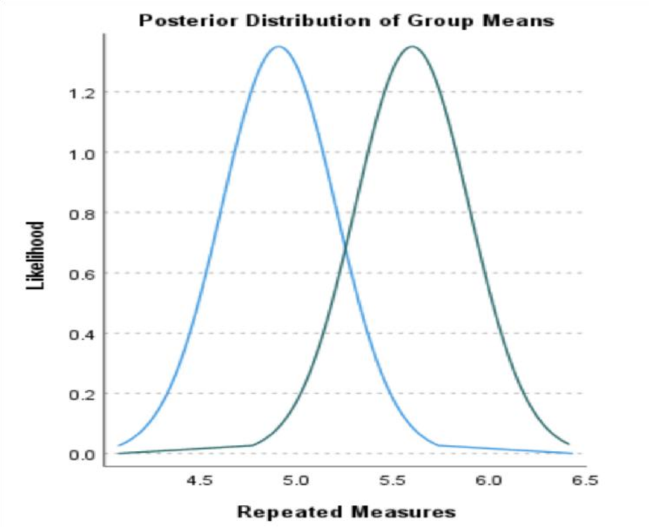

Figure 6. Posterior Distribution with Outlier.

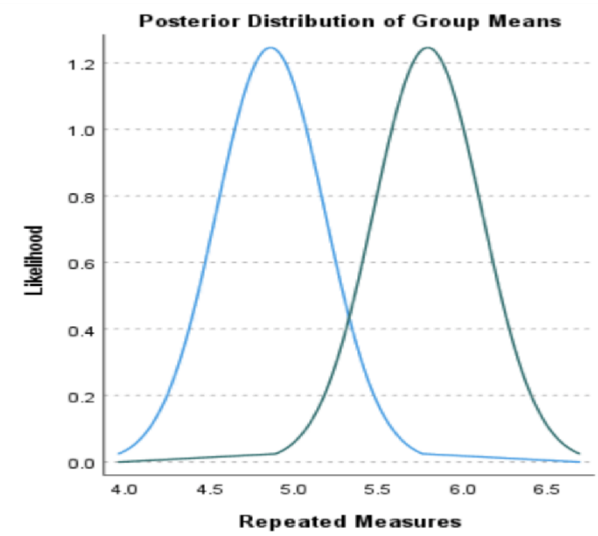

Figure 7. Posterior Distribution without Outlier.

It is also notable that there was an outlier observed when comparisons were made between the Vuzix Blade without sound condition and the Vuzix Blade with sound condition. Of the 6 participants who used both the Vuzix Blade with and without sound, there was only one individual who scored the Vuzix Blade with sound worse than the Vuzix Blade without sound. For this purpose, two charts have been created, Figure 6 which includes the outlier participant and Figure 7, which does not include the outlier participant.

It can be observed that there is a notable difference between the scores for Vuzix without sound and Vuzix with sound, this is accentuated when the outlier is removed from the analysis.

In terms of qualitative analysis, every user had the opportunity to provide additional comments at the end of every post-experiment survey they took. These comments were collected, analyzed, and separated into “positive” comments, “neutral” comments, or “negative” comments based on observation. These metrics counting how many positive, neutral, or negative comments were received regarding a certain task were used in the qualitative analysis to provide another outlook on how the users perceived the devices.

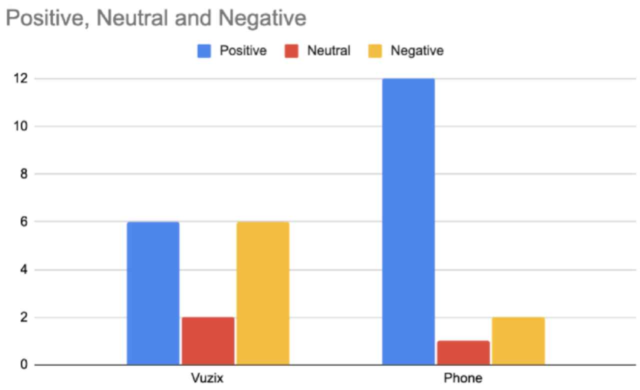

Figure 8. Positive/Negative Comments (Device).

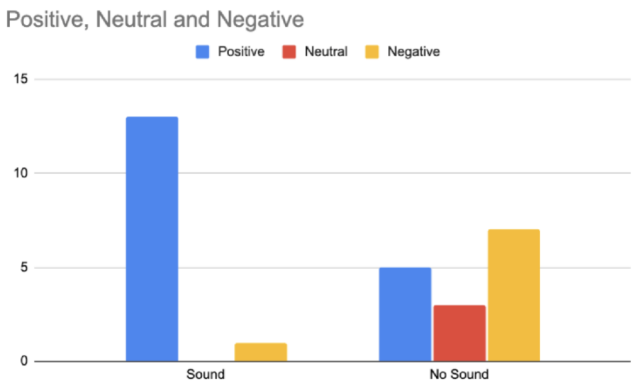

Figure 9. Positive/Negative Comments (Sound).

Figure 8 shows the amount of positive, neutral, and negative comments regardless of whether that device included sound or not.

There is a clear difference between the amount of positive responses received and the amount of negative responses received between the two devices. These findings are purely observational. Figure 9 shows the amount of positive, neutral and negative responses provided based on device with and without sound.

There is even a greater disparity between these two conditions than there was in Figure 8, showing that the comments regarding devices that included sound were much more positive than the devices that did not include sound. It is also worth noting that in the "No sound" condition, there were more negative comments than there were positive comments.

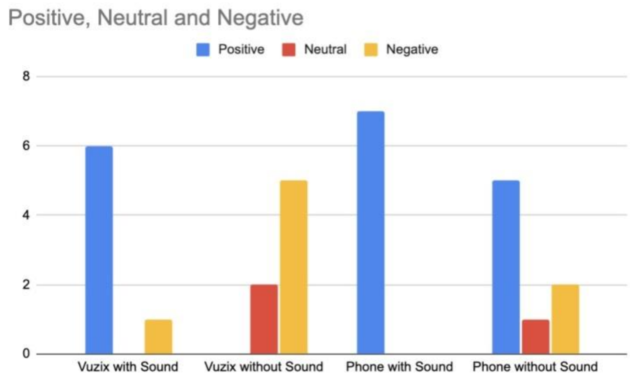

Figure 10. Positive/Negative Comments (Device/Sound).

Figure 10 takes the same data that was used to create both Figure 8 and Figure 9, and breaks down the comments, allowing for a more detailed analysis.

Some factors of this figure are worth noting, such as the fact that the "Phone with Sound" condition had only positive comments, no neutral or negative comments. Additionally, on the opposite end of the scale, "Vuzix without Sound" had no positive comments, with all of the comments about that condition being either neutral or negative, with the negative comments outnumbering the neutral comments.

6.6. Discussion

This experiment continues an important investigation into the use of AR technology at historical sites. There was no statistical significance across any of the comparisons between the mobile phone and Vuzix Blade. One possible explanation is that there are no characteristics in either device that were superior to the other. For example, most participants found using the Vuzix Blade to be novel and fun, while the phone was simply familiar to the user and fit their mental model, but both were enjoyable experiences. Previous research has shown that perception positively affected satisfaction [56]. Hence, the intimate familiarity with the phone and it's functions could be one reason why users enjoy using the device.

Work on retail experience may also shed light on the insignificance between devices. Research demonstrate that AR gives users the ability to perform tasks better while being entertained [57]. This would be reasonable as the majority of participants responded to the Vuzix Blade and mobile phone in this way. While being fun to use, the Vuzix Blade received many comments about it's bulkiness and physical form. The mobile phone, on the other hand, had higher responses on ease of use.

Figures 4 and 5 are clear visual indicators of how usable participants felt each device was, and also their opinions on the presence of sound in the different tasks they performed. Figure 5 demonstrates that participant scores for the no sound condition and the sound condition were very similar to one another. This indicates that the addition of sound may not in fact have that much of an effect on their overall approval of a specific device.

Figure 4 however, highlights that users seemed to prefer the phone over the Vuzix Blade, but not enough for it to constitute a significant difference. This indicates that there is a need for a re-testing this scenario with larger sample sizes, but also indicates that perhaps if the novel device being used was more similar to a mobile phone, users may be more approving of the device.

Figures 8, 9, and 10 present different results than the data shown in Figures 4 and 5. This may be due to the fact that Figures 8, 9, and 10 were based on qualitative data focusing more on user preference rather than the quantitative data that was presented in the first two figures, which emphasized usability of the devices.

Figure 8 indicated that users found the phone to be a preferable device to be used, with the positive responses to the phone outnumbering both its own negative response and the positive responses to the Vuzix Blade. Additionally it is worth noting that the Vuzix Blade had as many positive responses as it did negative responses.

Figure 9 highlights different aspects of the results observed in Figure 5. In Figure 5, it was shown that the inclusion of sound did not have much effect on the eventual outcome of the usability of the device. Whereas in Figure 9, it can be seen that the tasks that featured sound had many more positive comments on them, surpassing both its own negative comments and the positive comments of the devices that did have sound. This data suggests that perhaps users saw the inclusion of sound can make a significant difference.

Figure 10 illustrates more specific details that can be read from the data. For example, the fact that “Phone with Sound” received only positive feedback indicates that the participants preferred this condition to every other condition, seeing as every other condition had at least one negative comment. On the other end of the spectrum, “Vuzix without Sound” received no positive comments, and the negative comments outnumbered the neutral comments. This indicates that while there were no significant differences in usability, there may be significant differences in preference, which would need more in-depth research to be fully explored. One last notable point is the fact that the “Vuzix Blade with sound” had more positive comments and fewer negative comments than the “Phone without sound”, however still stated that they would generally prefer the phone over using the Vuzix Blade. This draws questions about whether the inclusion of audio is enough to counter the familiarity and ease of use when being compared to a device such as the mobile phone.

The potential issues with each device were highlighted mostly by short responses in the exit survey. Sixty seven percent of the participants claimed that mobile phones would be the best device for use at historical sites. The other thirty three percent said the Vuzix Blade would bring an immersive and new approach. When asked about features that participants would like to see, almost every comment was related to the Vuzix Blade. At the qualitative level it is clear that Vuzix Blade lacks some features that would allow users to enjoy it in everyday life but they are interested in using it. As for the phone, qualitatively and quantitatively it scored well with almost perfect scores and positive responses, again perhaps mainly due to familiarity.

7. CONCLUSIONS

Investigating the development of AR technology, and being aware of current developments in the field, it is clear to see that there is a great possibility in increasing understanding historical sites. AR is becoming a major technology that will eventually change society, through both handheld and wearable technology. The introduction of AR technology could provide communities with an immersive and interactive way to learn more about where they live. comments.

The experiment allowed AR to be observed and this demonstrated the potential for the future use of AR at historical sites. This should allow future research to be conducted in a comprehensive and well-grounded manner. In particular, this study provided an investigation of three AR devices for use at major historical sites, as well as measuring satisfaction differences in their characteristics. Due to COVID-19 subject sample size in this experiment was limited, but significance of a difference in satisfaction metrics when comparing devices was found.

Depending on the device, the tasks observed in this experiment were slightly different, but all had the same premise. The mobile phone tasks instructed each user to utilize the Artivive application to scan images within the self-guided tour provided on the laptop. Once scanned, the image on the mobile device would change, turning into a video that would slideshow through a variety of images, usually showcasing older locations from the fort, related to the original image scanned.

The Vuzix Blade tasks caused each user to move through videos that were taken from Artivive. They could then read more about Fort Ontario State Historic Site from the self-guided tour.
Due to the simpler nature of the AR Glasses device, and since the user was not able to interact with the screen during the test, the researchers compiled the videos that were used in other portions of this research into one extended video compatible with the AR glasses. This allowed the transfer of information from device to user, without worrying about the user being unable to directly interact with the screen and having direct control over the video progression.

After each section of the test (Artivive, Vuzix Blade, and AR Glasses), the subjects answered questions about how they felt about that specific device (both the enjoyability and the usability of the device). At the end, the subjects were asked a variety of questions about the future potential applications of this type of technology at historic sites, as well as any issues they experienced during the testing.

This experiment demonstrated that static AR devices like the AR Glasses were found to be unsatisfactory. However, the Vuzix Blade AR device was observed by the participants to be enjoyable, innovative, and fun. The difference observed here may be due to the ability to physically interact with the Vuzix blade and phone.

The results of this experiment also provided an understanding of AR and sound use at historical sites. Through splitting devices between use with and without sound, notable differences could be observed (Figure 10). Having an audio guide, in addition to the AR technology, was clearly something that users enjoyed (Figure 9).

Since the COVID-19 pandemic is still a relevant and serious threat, the sample size was limited. No statistical significance was found, however there were interesting conclusions that could be drawn from the qualitative data.

7.1. Experimental Limitations

The most obvious hindrance to this research was linked to the COVID-19 pandemic. The participant pool for this experiment was kept small, which resulted in a relatively low sample size.

A limitation of the low sample size was that generalization was almost non-existent. The small, local population had similar educational, demographics, and familiarity with AR technology. The only major difference in the population sample was in terms of age, which may allow for an understanding of a broader age range who visit Fort Ontario State Historic Site.

The AR devices also had a number of limitations, mostly pertaining to the Artivive application not being compatible with the headset devices. The Vuzix Blade was unable to download the application and the AR Glasses device would not be able to scan the image required to initiate the slideshow. Due to these limitations, in the case of the Vuzix Blade, small videos of each interactive photo were used for subjects to view, along with the self guided tour. The biggest obstacle outside of this, was that the touch-bar caused subjects to need time to adapt their vision. The AR Glasses had a phone placed within the device, this provided with a compiled video of the same videos on the Vuzix Blade. Since each device was slightly different, any comparison is not ideal.

In the second experiment undertaken, the high scoring on the questionnaire for the smartphone was close to causing a ceiling effect. This makes it difficult to discriminate if sound had as significant of an impact as it did for the Vuzix Blade.

Additionally, a small sample size was a major limitation, a larger participant group would allow for a deeper analysis of the data collected. This can be easily observed in Figures 6 and 7, where one user supplying an outlier response can cause a significant change in the graphs that represent the general opinion towards two different conditions. This sampling size issue was due to limitations brought on by the current COVID-19 pandemic.

Another limitation that occurred in the second experiment was in regard to the shortcomings of the technology used. Both devices in this experiment had been used in a previous study, with only audio being added as an additional factor for analysis. A wider range of devices, differing on price ranges, capabilities, and novelty may provide more insight into what is responsible for the user preferences for specific devices, or more importantly, what is preventing a preference for specific devices.

7.2. Future Work

In future, any options for expanding the participant pool would improve the significance and veracity of the results drawn from the data. Random sampling of a range of demographics that reflect the diverse population of visitors to Fort Ontario would be of enormous benefit to any future work.

Future work should also look into the possibilities of increasing the number of AR devices being tested. Additionally, adding more modalities may also prove to be beneficial.

In addition to adding modalities, future research could also increasingly utilize the immersive possibilities of mobile devices. In this study the mobile device was seemingly the favorite among the AR technology tested. Expanding the capabilities available will allow the already enjoyable experience to be improved. This could allow historical sites to provide the learning experiences for their community.

Following the example of other well established research on museums and related areas may address some of the issues observed in this research. For instance, in a recent study undertaken at a cultural heritage site, AR was found to be useful when combined with an application offering a variety of media; user control; location guide, participation questions, and several other unique characteristics. The application used in this research utilized different types of media which users found useful [58].

Past work on the integration of AR and audio involved mobile devices incorporating natural sound. During a period of rapid growth of AR technology over the past decade sound has been integrated into both mobile and headset devices [59, 60]. While this research greatly aided the use of AR technology at historical sites, there is much to learn about which specific technology would be most beneficial for educational purposes.

Participants in the second experiment specifically noted the lighting, and that using a single eye for the Vuzix Blade was difficult at times. The continued use of AR headsets may need to be stationary rather than designed for a seamless mobile experience. This is due to AR devices not being able to exist in a way that works so perfectly with our other senses at present.

Additionally, smartphone devices can continue to be explored as they were found to be enjoyable as an AR device in this particular setting. It should also be noted that additional modalities could be an answer to improvement, as sound alone didn't show significant differences between devices to mark it as important.

There is very much a reason to believe AR can play a large role at historical sites in order to provide an immersive experience for any local community to learn about where they live.

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