Improving User Experience for Lost Heritage Sites with a User-Centered Indirect Augmented Reality Application

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Abstract. Using digital media technology, e.g. augmented reality, to convey information about cultural heritage, is becoming increasingly more common. While augmented reality is considered useful and innovative for this purpose, systems based on this technology do at times fail to meet the end users' needs. This paper describes the continued user-centered development and evaluation of an indirect augmented reality application, used to convey information and to visualize the lost Viking ring fortress of Aggersborg, with the larger goal of improving the user experience currently available at the Aggersborg site.

The app was evaluated on users representing the visitors of Aggersborg. The participants were evaluating their user experience of the Aggersborg information board with and without the app as well as the usability of the app by answering user experience and usability questionnaires. It was found that the app did significantly increase user experience for children, while not doing so for seniors.

Keywords: Augmented reality · Indirect augmented reality
User experience · Virtual cultural heritage · Narrative

1 Introduction

Mediating cultural heritage to the public using digital technologies is a field that keeps evolving. Cultural heritage sites, which have been eroded away by time, often suffer from poorly representative visualizations of what the sites looked like in their prime. Use of digital technologies is therefore considered useful in this context [1]. Augmented Reality (AR) has in particular been claimed to be a useful means of conveying information about cultural heritage [2]. AR is currently being integrated into cultural heritage exhibits to provide the user with an interactive experience [3]. However, it has been claimed that there is a gap between the end users and the designers of such applications, indicating a lack of understanding of the users' needs [4,5].

This project is the continuation of previous work done by Jakobsen et al. in collaboration with Vesthimmerlands Museum [6]. The overall aim of this project

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is to develop a smartphone application that visualizes and conveys information about the Viking ring fortress of Aggersborg through Indirect Augmented Reality (IAR). An interactive base system, which allows users to explore Aggersborg in IAR from three preset locations has previously been developed [6]. An iterative, user-centered design process has been employed in the development, with Vesthimmerlands Museum as primary sparring partner.

The main contribution of this project is a summative evaluation of a user-centered designed and implemented IAR application in terms of usability and user experience compared to experiencing the existing signage at the Aggersborg site.

2 Previous Work

This section provides an overview of the field of cultural heritage, presence in relation to Virtual (VR)- and Augmented Reality (AR), Indirect Augmented Reality (IAR) and digital storytelling.

2.1 Cultural Heritage

Over the past years, efforts have been put into preserving cultural heritage in digital forms [7]. Systems need to be adapted to make use of what current technologies offer, they have to meet the requirements of potential visitors [4,7]. By doing so, the digitized cultural heritage becomes more accessible, available and usable to the public [7]. According to Bachi et al., cultural heritage belongs to the public through the use of digitalization, which encourages more participation from the public. Here mixed reality can be used to virtually transport the user through time and space to a cultural heritage site as it would appear during its prime. Slater described telepresence and place illusion as the concepts of a user feeling located at another place or time and adapting to different bodies of the self [8].

2.2 Indirect Augmented Reality

The proposed system is based on the concepts of conventional AR, meaning superimposing imagery on top of a live camera feed on a handheld device [9]. However, as the terrain of the Aggersborg site is barren of features easily trackable by a computer vision system, alternative methods had to be investigated. Here Indirect Augmented Reality (IAR) can be a substitute for conventional AR without the same problems.

Wither et al. have found that the prominent issues related to conventional AR in outdoor use include either the requirement of computer vision to track features in the real environment, or that it relies on the use of integrated sensors which can result in imprecise alignment [10]. These factors make the alignment of a virtual visual element on top of a live camera feed a challenge. IAR addresses the alignment issue by compositing a 3D-rendered layer on top of a panoramic

image of the real-world location; thereby eliminating the need for calculating the alignment between the virtual and real elements in real time. Similar projects have been published by Liestøl et al. who employed a completely pre-rendered environment and GPS locations of the user to use AR systems as a window into the past. Liestøl et al. named this method "situated simulations" [11–14].

3 Materials

The application that was made in this project builds on a foundation which was developed in a previous project [6]. The previous application used IAR to display a 3D-rendered model of Aggersborg on top of 360° photos taken at three locations at the Aggersborg site: at a platform, at the north gate and in the center of the structure. An interface allowed the user to switch between viewing the three preset locations, each showing the ring fortress from a different perspective. In order to align the virtually rendered scenes with the real world, a calibration interface was implemented. The user has to physically stand at the platform and align the app by framing the nearby church in a live camera view and pressing a button. This produces a reference direction, from which an offset can be calculated. This offset is then used to produce a virtual scene, correctly aligned with the real world.

The contribution of the present work is a collaborative design and development process with Vesthimmerlands Museum who acted as the user experts. This collaboration was carried out through multiple meetings with both museum staff, exhibition creators and archaeologists. At these meetings it was decided that to improve the user experience of Aggersborg the system should contain an added narrative and auditory as well as visual elements that help support the users' immersion, when using the app as well as convey factual knowledge. The interface should be intuitive and easy to use, with high affordance, since users span a wide range of age and experience with using apps.

One of the important aspects of the application is its user-centered development. For example, it was considered important to account for both totally absent gyroscopes as well as gyroscopes with poor accuracy in the design. This was achieved by allowing users to disable gyroscope orientation completely, if the accuracy was too poor to produce a satisfying result, and instead use touch to look around in the scenes. In case that no gyroscope was available, the touch navigation would be the default and only option.

Furthermore, an eight-screen tutorial was added at the start of the application, which provides especially new users with a means of understanding the interface and functionality. While it contains a lot of text, it ensures that a thorough description is available for inexperienced users. By adding a skip button, the users can also opt to skip past the tutorial.

The Graphical User Interface (GUI) also exemplifies the user-centered focus. The GUI, including the visual representation of the guide, went through several iterations. Its foundation in terms of design was initially conceived with the collaborators at the museum, using storyboards to consider possible use cases that

might be encountered when situated in the context. Various heuristic evaluations and quick and dirty tests helped inform further iterations of the GUI. To make it as user friendly as possible, its buttons were kept simplistic and clear. Because of their non-trivial functions, descriptive text was preferred over icons to illustrate the buttons' functionality. Rather than nesting all buttons in a menu, most buttons were placed in corners of the screen, providing easy access to currently available and relevant functionalities.

3.1 Description of System for Testing

The prototype of the application that was used for testing, see Fig. 1, functioned as follows. When entering the app, the users encounter an introduction, followed by the tutorial. After this, the interface guides the users through aligning the app. After the alignment process, the users are presented with a skybox showing the 360° platform scene, which they can rotate and explore using either the gyroscope of their phone or by dragging on the screen. As a big focus was on the narrative and immersive elements, Svend, a fictive local Viking would act as a virtual guide for the site. When pressing his portrait, he tells a distinct story for each of the three locations, thereby providing factual historical information that is not mediated through the visuals of the app. A treasure hunt mechanic acts as an incentive for users to explore the site; a hidden object is present in each of the three locations for users to find, and once found, users are able to inspect the object more thoroughly in 3D by rotating it and zooming in on it. Textual background information about the object is included as well. For the case of misalignment, a recalibration guide instructs the users how to go through the calibration process again.

Fig. 1. Example of the final iteration of the developed application.

4 Evaluation

The aim of the evaluation was to assess the current prototype iteration in terms of user experience and usability, when using it in its intended context. The purpose of this was primarily to evaluate the application as a supplement to the existing possible activities at Aggersborg, as well as to inform the future design processes by identifying potential usability issues and issues detracting from the user experience.

Based on this, the following research question of the project was formulated:

How does an IAR application, which was developed using user-centered design affect the user experience of visiting the Aggersborg exhibit when compared to the existing information board?

In order to evaluate if the application was a positive addition to the site, as originally intended by the museum, the evaluation was approached as a comparison between the existing outdoor activity at Aggersborg, the information board, and the app. If the app yields a more positive user experience in terms of being a more interesting and fun activity than reading the existing information board, then the app is considered a positive addition to the site. Also, an evaluation of the usability of the app was conducted.

4.1 Test Design

It was chosen to conduct the tests at the Aggersborg site, thereby mimicking the intended context that the app should support. Also, this location allowed for evaluating the user experience of the app in comparison with the information boards. The study relied on questionnaires for gathering anonymous responses from the participants, in the hope that this and their anonymity would decrease the chance of reactivity and experimenter effects as well as demand characteristics, which are important factors to consider when relying on self-reporting [15].

The questionnaire for evaluating the user experience was based on a mix of intrinsic motivation index (IMI) questions for evaluating users' interest [16], as well as relevant questions of our own design. Standard Usability Scale (SUS) questions were used for evaluating the usability and interface of the app [17]. In order to obtain interval data, 7-point Likert scales were used on all questions. After having evaluated both the information board and the app, a short, comparative questionnaire was administered at the end. This questionnaire asked for preferences between the two experiences, and also allowed for the participants to provide more elaborate feedback. Vesthimmerlands Museum estimated that the primary visitors of the site were people aged 60+ as well as families with children. Based on this, people aged 60+ and children were selected for the test. Since the two target groups were vastly different, the questionnaires were kept short and concise. In order to obtain representative samples of these two demographics, the museum was helpful in providing access to 70 school children for testing as well as eight people aged 50+.

4.2 The Field Tests

Two field tests were conducted over the course of two spring days at the Aggersborg site in order to evaluate. This was primarily done in order to evaluate the user experience on the two main target groups and to identify usability issues. The first study encompassed the school children and the second study, conducted two weeks later, encompassed the 60+ participants (hereafter denoted test A and B, respectively). In order to maintain validity, both tests were conducted in identical settings; only participants would differ. One Samsung Galaxy S7 and two Galaxy S6 Android phones were used for testing. In order to be comparable in terms of validity and reliability, the field tests were kept as identical as possible.

Test A Description. On arrival, the 70 children were split into three groups of equal size by their teacher. During the first test, it quickly became obvious that the school children spent far longer time filling out the questionnaires than expected. Also, since some children took longer than others to fill out the forms, and others not complying with the instruction of filling them out, it became difficult to determine which child needed to fill out remaining forms. This lead to inconsistencies in the resulting questionnaires. In total 18 questionnaires for the information board, 22 for the app and 36 comparative questionnaires were answered.

Test B Description. The test session with the 60+ participants was conducted with exactly the same setup as for the children. The participants were all locals from the civic association and were gathered by the museum. The test yielded data from eight senior participants aging from 50 to 68.

5 Results

The data of the two groups of children and seniors was kept separate as the data showed that there were some differences between the groups. A two sample t-test was conducted on the questionnaire, which showed that there was a significant difference in many of them, such as "Was this activity boring?" ($p < 0.05$). Here, the seniors were much less likely to deem the information board boring than the children were.

For the evaluation between the participants experiencing Aggersborg with and without the app, a dependent paired t-test was conducted and the results with a distribution plot of the answers can be seen in Fig. 2. The results show that the difference in user experience for the seniors ultimately does not vary greatly between the information board and the app. The results show that there is no significant difference, as questions such as "Did you enjoy the experience?" ($p > 0.05$) showed that there is only minor variance in the distribution. The method of using a dependent paired t-test was also used for investigating the children's answers. Contrary to the seniors, the results show that there is a significant difference between the information board and the app when it comes

to the enjoyment of the experiences. Especially questions such as "This activity was fun" ($p < 0.05$) show that the children found the app to be more fun to use and that they found it better to hold their attention.

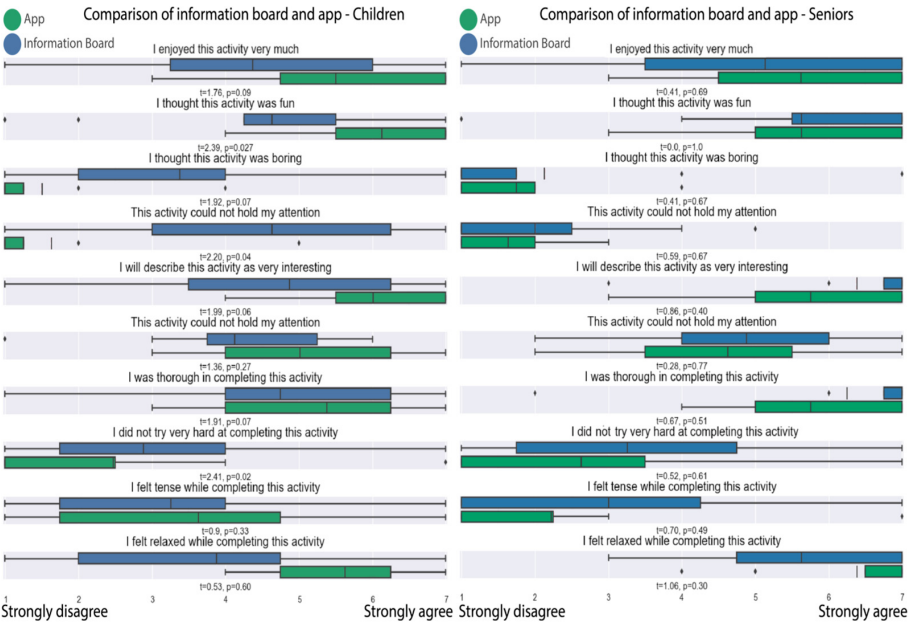

Fig. 2. Boxplots showing the distribution of the answers given on the questionnaire when the seniors and children were asked to assess the information board (blue) and the app (green). The x axis shows the answers given on a Likert scale from 1 to 7. 1 is strong disagreement with the question, while 7 is strong agreement with it. (Color figure online)

5.1 Test A & B Observations

The app was generally received positively by participants in both groups. A number of similar usability issues were observed in both test A and B; specifically in the tutorial section, which at times led participants to either not complete tasks correctly or at all. The following sections summarize the observations from both tests.

Test A Observations. The children generally seemed engaged with using the app, although some of the errors they made might suggest that they did not read the tutorial text. An example of this was seen in the alignment procedure, where several of the children seemed confused by the tutorial. Another example was that a group of children went into the terrain looking for physical artifacts rather than searching for the artifacts within the app. Another group of children

thought that the live camera feed for alignment was the actual experience the app had to offer, and needed guidance for entering the IAR scene. Several children seemed impatient when listening to the virtual guide, and promptly shut him off when told that they did not have to listen to it all.

In spite of the initial difficulties with the tutorial, 70% went physically to all of the three locations, and seemed able to follow the instructions of the app.

Test B Observations. The seniors similarly had difficulties with the tutorial. From their behaviour, it was clear that most read all the available text, but rather than just exploring the app, as the children did, many were hesitant to move forward through the interface, and had several follow-up questions. This indicated that the tutorial, which contained only brief texts, was not sufficient to be self-explanatory for this user segment.

6 Discussion

As shown in the results, the app did not statistically improve the user experience of Aggersborg for the seniors, but did so for the children. While the user experience for the seniors was not necessarily improved by the app, they did prefer the app when directly asked to evaluate their preferences. The children did find the application to be more engaging and exciting compared to the information board. As it was better at keeping their attention, it might be more successful in conveying the information of the site; especially the visual appearance of the no longer existing fortress.

The results for the participants' self-perceived competence showed that for both the seniors and the children found the app both intuitive and easy to learn and use. The seniors assessed that most visitors would be able to learn to use the app by themselves, despite that half of the senior participants reported that they did not have a lot of experience with mobile apps in general. Most felt that they did not need long to learn to interact with the app. This is considered important, as the app needs to be easy to use and engage with for visitors of Aggersborg. However, a large part of the children felt more insecure in using the app by themselves, which might be less important as most children visit Aggersborg in some sort of group. Lastly, when asked about intrinsic motivation questions, both groups showed statistically no difference between the two experiences. This indicates that the app was not more intimidating than the information board, despite having more features. However these self evaluations are somewhat contradicting the observed behavior of the participants. Some participants were not able to execute the commands in the tutorial, and some did not indicate to fully understand parts of the interface.

All of this indicates a positive impact on the user experience as a whole, suggesting that both the mediation of information as well as the user experience were satisfactory to the participants. The results point towards that the user experience of visiting Aggersborg was improved for the children, while for the

seniors it was on par with that of the information board. The fact that the app appears to provide the users with a positive experience when visiting the site, gives the indication that the approach and its content is able to meet the needs of the users of Aggersborg.

The tests first and foremost posed concerns in terms of the small sample size for the 60+ segment, which threatens external validity and generality. Also, since these participants are connected with the civic association, they are likely biased towards favoring any new action taken to improve upon the site, as also reported by the museum. However, this bias may also be affected by the participants' experience with technology, as the information board is simpler than the app. This, as well as the fact that they volunteered for the test may also be of concern in terms of both internal and external validity [15].

In general, efforts were made to reduce group threats by randomizing all participants as well as counterbalancing the order of events, but because of the small sample of 60+ participants, as well as the chaotic nature of the session with the children, it was not possible to counterbalance all results. Also, allowing the participants to team up with whom they chose within their designated, randomized group, has likely reduced randomization. However, was assessed to be a more accurate representation of the likely behaviour of users when using the app on the site.

7 Conclusion

In conclusion, the IAR application improved the user experience for children by giving them a more overall complete experience compared to that of solely the information board. The user experience of the seniors was not improved in the same way, as they already had a positive experience from the information board in the first place. Despite this, the collaboration with the museum made it possible to develop an IAR application that could be enjoyed and utilized by both children and seniors, which would allow for historical correct information to be conveyed in a more interesting way than the information board. The application allows the users to explore and experience the site in their own way and pace, as it offers various functionalities to experience if desired. From the evaluation, it was found that while the various age groups have different opinions on the information board, they do in general find the application both engaging, easy to use and interesting.

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