Mobile Augmented Reality for Cultural Heritage: A Technology Acceptance Study

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Abstract

We have developed a mobile augmented reality application with historical photographs and information about a historical street. We follow a design science research methodology and use an extended version of the technology acceptance model (TAM) to study the acceptance of this application. A prototype has been developed in accordance with general principles for usability design, and two surveys have been conducted. A web survey with 200 participants that watched a short video demonstration of the application to validate the adapted acceptance model, and a street survey, where 42 participants got the opportunity to try the application in a live setting before answering a similar questionnaire and provide more concrete feedback. The results show that both perceived usefulness and perceived enjoyment has a direct impact on the intention to use mobile augmented reality applications with historical pictures and information. Further a number of practical recommendations for the development and deployment of such systems are provided.

Index Terms: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities—Evaluation/methodology;

1 Introduction

Several cultural heritage institutions have recently made their own mobile augmented reality applications with cultural heritage resources such as historical pictures and information. Examples include the Philadelphia Department of Records [5], the city of Christchurch [4], the Museum of London, the Netherlands Architecture Institute and the Powerhouse Museum in Sydney.

However, despite the popularity of this type of applications and the fact that user acceptance of technology has been of interest for both researchers and practitioners for decades, little has been done to study users' acceptance or willingness to use this type of application.

A number of studies have examined the acceptance of mobile applications and services [11, 13, 21, 27, 28, 40, 43], many adding particular aspects to the traditional technology acceptance model (TAM) based on limitations of TAM for mobile application [45]. Recent studies have also examined the acceptance of mobile tourist guides [32, 37]. There is at least one study that has examined the acceptance of mobile augmented reality applications in general [41]. Acceptance studies of mobile augmented reality applications with cultural heritage resources are rare.

The aim of this paper is to report on a study on the factors influencing the acceptance of such systems, and to what extent there seems to be interest in these types of applications.

In section 2 we provide further background on the use of mobile augmented reality in the area of cultural heritage. Our research method is presented in section 3, before presenting the developed application in more detail in section 4. The evaluation of the application is described and discussed in section 5 end with recommendations for practice, before concluding the article.

2 Background to Augmented Reality in Cultural Heritage

Augmented reality (AR) aims to enhance our view of the world by superimposing virtual objects on the real world in a way that persuades the viewer that the virtual object is part of the real environment [6]. Mobile augmented reality systems provide the same services as augmented reality systems without constraining the individual's whereabouts to a specially equipped area [22]. According to [3] mobile augmented reality is one of the fastest growing research areas in the augmented reality area, due to the emergence and widespread uptake of smart-phones that provide powerful platforms for supporting augmented reality on a mobile platform. Current smart-phones and tablets combine a fast processor with graphics hardware, a large touch screen, and relevant embedded sensors such as camera, GPS, Wifi (for indoor positioning [24]), compass, and accelerometer, making them ideal for both indoor and outdoor AR [4].

According to [20] "Museum educators arguably have always been in the business of augmenting reality, creating bridges between objects, ideas, and visitors". Both artifacts and areas are often accompanied by extra material such as descriptions, pictures, maps, or movies. For archaeological sites, there are also guides with pictures of how a site looks now printed on normal paper and images of how it looked in the past printed on transparent material. Audio guides are also much used. An approach for enhancing physical mock-ups with virtual overlays are reported in [26]. Mobile augmented reality applications takes the technology a step further and lets the institutions provide information to the user, where the user is located. They also create publicity and help institutions reach out to new audiences [5].

The following should by no means be regarded as a complete list of all mobile augmented reality projects in the cultural heritage sector. However, it describes the shift from projects using augmented reality systems with head-mounted displays to projects using contemporary AR systems with smart-phone applications.

The Archeoguide system [44] is a mobile augmented reality system for cultural heritage sites launched in 2001. The system was built around the historical site of Olympia, Greece, and provided personalized contextual information based on the user's position and orientation. Three different mobile clients were supported within the system: a laptop, a tablet and a Personal Digital Assistant (PDA). The full augmented reality functionality was only available on the laptop client. This client required the use of a see-through head-mounted display with an external web camera and a digital compass, a backpack with a GPS receiver, a laptop, wireless communication equipment, and a battery. The laptop system used a hybrid approach where a GPS and compass system was used to get a rough estimate of the user's position before vision-based tracking techniques were used to find the exact position and orientation.

The iTacitus project[1] was a European research project 2006-

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[1]Intelligent Tourism and Cultural Information through Ubiquitous Ser-

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2009. One of the systems developed under the iTacitus program was the augmented reality presentation system for remote cultural heritage sites [46]. The system did not use a head-mounted display, but rendered augmented information on top of the camera feed of a commercial device. For positioning, the system relied solely on image-based tracking techniques.

The CityViewAR-system [4] is an example of mobile AR in the city. In [4] it is particular emphasized the use of the technology for supporting learning. Students can use this mobile phone application to "see" buildings in the city of Christchurch as they were before the 2011 earthquake. This application can obviously also be used by the general citizen. In [23] a mobile app uses AR technology to explain the history and architecture visually at a real building outdoors.

A number of cultural institutions have launched their own augmented reality applications lately. Examples include the Philadelphia Department of Records, the Museum of London, the Netherlands Architecture Institute and the Powerhouse Museum in Sydney. As an example, the Augmented Reality PhillyHistory.org application [5] is built on top of Layar, an augmented reality application for smart-phones that supports both Android and iPhone/iOS. Layar displays points of interest (POI) as markers on top of the live camera-feed from the smart-phone. It handles the positioning and rendering of information on the device and lets the application developers focus on building a web service with the information they want to include. The application enables users to view historic photographs of Philadelphia as overlays on the camera view of their smart-phones. The application contains almost 90.000 geo-positioned images. 500 of these can be viewed as transparent images positioned in 3D, and a selection of 20 contains additional explanatory text developed by local scholars.

3 Research Method

Through Trondheimsbilder.no one has access to a large collection of historical local photographs on an Internet-platform. The website is frequently visited by historians and members of the local historical organizations and new pictures are added regularly. In connection to work over the last five years in Wireless Trondheim Living Lab [1] we have developed and evaluated a number of applications combining local historical pictures with positioning, providing access to these pictures on a mobile platform close to where they were originally taken [17]. Although technically successful, we have failed to get much interest from users for these solutions. In [4] it is claimed that providing AR experiences on mobile devices can have unique benefits over offering non-AR content on the same topic, and we wanted to investigate the application of mobile augmented reality for presenting historical pictures. Feedback on the use of Trondheimsbilder.no and similar systems has indicated to us that such systems serve both a purpose (to learn about the city) and have a certain fun-factor, thus is hypothesized to have both hedonic and utilitarian purposes.

The following questions guided the research:

1. Do the previously established relationships between the constructs in the technology acceptance model (TAM) extended with perceived enjoyment hold for augmented reality applications with historical pictures and information?

2. Is there an interest in using augmented reality applications with historical pictures and information?

The first research question deals with the relationship between the constructs in the acceptance model. Van der Heijden [39] showed that perceived enjoyment and perceived ease of use were stronger predictors of intention to use a hedonic system than perceived usefulness. We wanted to find out if the same is true for augmented reality applications with historical pictures and information. This information can be used to find ways to make this type of applications more acceptable to users.

The second question deals with the interest in using this type of application. The aim is to discover if there is an interest and whether this interest is dependent on the application being available on a specific type of device. It is also desirable to know if people want to use this application in their home town or when visiting a new city.

We followed the guidelines for design science research [15]. The outcome includes two artifacts: a prototype of a mobile augmented reality system with cultural heritage resources and a technology acceptance model for this type of applications. The outcome also includes suggestions for further improvements of the prototype.

First a preliminary study was conducted to explore the need for an augmented reality application with historical photographs. A number of similar solutions were reviewed and stakeholders from local cultural heritage institutions were interviewed to gather requirements. Then, a prototype was developed and evaluated for usability. Based on the result from this, another design and development phase was performed. Different models for technology acceptance were reviewed and a questionnaire was designed. The questionnaire consisted of five major parts:

1. Perceived usefulness
2. Perceived ease of use
3. Perceived enjoyment
4. Behavioral intention
5. Individual variables

The measure for perceived usefulness was developed specifically for this project in line with the thinking of van der Heijden [39]. He noted that the original TAM scale was developed for utilitarian information systems and found that the measure for perceived usefulness was problematic because of the focus on improved job performance. Because of this, he developed a new set of items that were more appropriate for the partly hedonic system investigated in his research. These items have later on been used as an example of how to develop a set of reflective items that all measure the same idea within the perceived usefulness construct [33]. His items were too specific to be used in this research, but were used as a model when constructing a set of new reflective items, appropriate for an augmented reality system with historical information.

The scales used to measure perceived ease of use and behavioral intention in this research are based on two Likert scales developed by Venkatesh and Davis [42]. The scale used to measure perceived enjoyment is a seven-point semantic differential, developed by Chang and Cheung [7]. The use of this type of scale to measure perceived enjoyment or affect are suggested by Triandis [36] and is the same approach as was used in research by van der Heijden [39] and Chesney [8].

Two different surveys were conducted: a web survey with 200 participants who answered the questionnaire after having watched a video presentation illustrating the use of the application . This survey was preliminary used for checking the acceptance research model to investigate the factors influencing the intention to use this type of systems. Similar surveys have been used successfully earlier [14] for validating such research models, since it enables to get feedback from sufficiently many users to be able to apply the prescribed statistical techniques. Respondents were recruited from all of Norway by a market research company, thus we had no direct contact with the respondents.

A street survey was performed with 42 participants who all got the opportunity to try the application in practice in the streets of

vices

Trondheim before they answered the questionnaire, also providing more qualitative input. None of the respondents where known to us before being stopped on the street. As far as we know, there was no overlap between this group and the group answering the web-survey. The data from both surveys were used to have a closer look at the interest in mobile augmented reality applications with cultural heritage resources.

The format of the scales used in the street survey and the web survey were slightly different. Only the web survey used *proper* Likert scales that fulfill all of the criteria as listed by Uebersax [38]:

1. The scale contains several items.
2. Response levels are arranged horizontally.
3. Response levels are anchored with consecutive integers.
4. Response levels are also anchored with verbal labels which connote more-or-less evenly-spaced gradations.
5. Verbal labels are bivalent and symmetrical about a neutral middle.
6. In Likert's usage, the scale always measures attitude in terms of level of agreement/disagreement to a target statement.

The scales used to measure perceived usefulness, perceived ease of use and behavioral intention in the street survey were not genuine Likert scales but rather *semantic differentials* or *discrete visual analog scales (DVAS)*. The scales contain a full set of numeric labels but are only anchored with verbal labels at the upper and lower endpoints. They thus fail on criteria number four for Likert scales.

The use of only partially labeled scales can be defended. According to O'Muircheartaigh et al. [31], it is a common convention to use partially labeled scales in market and social research. However, some researchers (such as Krosnick and Berent [25]) have found that fully labeled scales are more reliable and may be preferable in terms of variance explanation. Then again, some researchers (such as Andrews [2]) have found otherwise. Furthermore, using fully labeled scales has its own problems as it can be difficult to find verbal labels for the intermediate points in all but the simplest three-point scales. In the end, it was decided to use partially labeled 7-point scales on the paper survey where there was limited space and fully labeled scales on the web survey where this was less of an issue.

The fifth part of the study asked about individual variables such as gender, age and historical interest. The street survey also asked about whether the respondent had experience with a tablet. In the web survey, there were two questions: the first asking about whether he or she owned a smart phone and the second asking about whether he or she owned a tablet.

Figure 1 shows the research model used in this study. This is the technology acceptance model with perceived enjoyment used by Davis et al. [9] and van der Heijden [39].

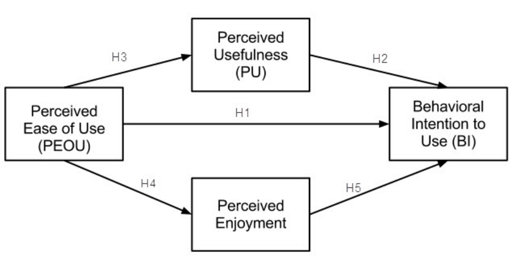

Figure 1: Research model (adapted from van der Heijden [39])

Four constructs are included in the model: perceived enjoyment, perceived usefulness, perceived ease of use and behavioral intention. While it was expected that the predicative strength of the paths may change, it was expected that the structure of the relationships from TAM will hold for this model as well. This lead to the following hypotheses:

- **H1** There is a positive relationship between perceived ease of use and intention to use.
- **H2** There is a positive relationship between perceived usefulness and intention to use.
- **H3** There is a positive relationship perceived ease of use and perceived usefulness.

Perceived enjoyment has the same position in the research model as perceived usefulness. This lead to the following hypotheses:

- **H4** There is a positive relationship between perceived ease of use and perceived enjoyment.
- **H5** There is a positive relationship between perceived enjoyment and intention to use.

4 Overview of the Application

The application presented in this paper is called The Historical Tour Guide. It is a location-aware mobile information system that uses mobile augmented reality to present local historical photographs in Trondheim. The system is built atop CroMAR [29], a system that uses mobile augmented reality to support reflection on crowd management.

There are three ways to access information in the application:

1. Clicking on a point-of-interest
2. Clicking on a photo in the list of available photos
3. Looking on the map

All three methods can be combined with filtering to look at photos from a specific decade. We will below present the main functionality of the system.

- Augmented Reality View: The augmented reality view is the main view of the application where points of interest (POIs) are shown as floating icons overlaying the camera feed. The name of the application is shown in the toolbar at the top. The view is shown in figure 2.
- Photo Overlay: Figure 3 shows one of the application's transparent photo overlays. These let the user see historical images over the present day scene. The buttons in the toolbar at the top of the screen are used to close the overlay or go to the detailed information view belonging to the picture.
- Detailed Information View: Each of the photographs in the application has an associated detailed information view. One of these is shown in figure 4. It contains a description of the motive and let the user know when the picture was taken, the source of the photograph and the name of the photographer.
- Timeline: The timeline is always visible at the bottom of the screen. It lets the user filter the amount of incoming information so they only see photographs from a specific decade. The selected decade is marked in green and written in the upper-left corner.

- Map: Figure 5 contains a screen shot of the application's map. It shows the user's current position and the position of photos from the decade selected on the timeline. Each pin is tagged with the name of the photo and the distance from the user. It is not possible to open photographs from the map in this version of the application.

- List View: Figure 6 shows the application's list view. This view shows the user a list of all photographs from the selected decade and provides a convenient method to open detailed views without having to locate the associated markers.

Figure 2: AR View

Figure 3: Photo overlay

Figure 4: Detailed information view

Figure 5: Map

5 Evaluation and Discussion

This section presents the descriptive analysis of the results from the two surveys including investigating the stated hypothesis. We present first the results from the web-survey including the statistical analysis, before presenting the result from the street survey. A discussion including practical recommendations and limitations of the research follows.

Figure 6: List view

5.1 Results from the web-survey

In the web survey the age-range was between 20 to 45 years old, with a mean age of 33.3. 48% of the respondents were male. About a fifth of the respondents replied that they had used a similar application. The intention of this question was to see if the respondent had any experience with an augmented reality application. One of the negative aspects of conducting a web survey, is that there is no interviewer that can assist the respondents in completing the questionnaire. Because of this, the web survey also included a "do not know" option for two of the questions. Furthermore, instead of asking whether the person had any experience with a tablet, it was decided to ask whether he or she owned a tablet. A question on smart-phone ownership was also included. 81.5% of the respondents owned a smart-phone, while only 30.5% owned a tablet. 13.5% replied positively to the question on whether they had experience with a similar application while 44.5% responded yes to the question on whether they had read a book on local history.

Table 1 shows the descriptive results of responses on perceived usefulness.

The responses in the web-survey to pu1 ("By using the app, I can more quickly and easily find historical pictures and information"), pu2 ("By using the app, I learn more about history in Trondheim") and pu3 ("By using the app, I can quickly find historical pictures

Item	N	Min	Max	Mean	Median	Std. Deviation
pu1	200	1	7	5.35	6.0	1.181
pu2	200	1	7	5.34	6.0	1.171
pu3	200	1	7	5.39	6.0	1.202
pu4	200	1	7	5.08	5.0	1.393

Table 1: Statistical summary of web survey responses to items measuring perceived usefulness

and information from places nearby") all have a median of 6.0, a mode of 6 and a mean between 5.3 and 5.4. Item pu4("By using the app, I am more likely to find historical pictures and information that interests me") received a lower score than the other items. It still has a mode of 6, but the median is 5.0 and the mean 5.1.

Table 2 shows the descriptive results of responses on perceived ease of use.

Item	N	Min	Max	Mean	Median	Std. Deviation
peou1	200	1	7	5.31	6.0	1.233
peou2	200	1	7	4.87	5.0	1.361
peou3	200	1	7	5.16	5.0	1.182
peou4	200	1	7	4.97	5.0	1.223

Table 2: Statistical summary of web survey responses to items measuring perceived ease of use

On perceived ease of use in the web-survey all the items have a mode of 6 and a mean between 4.9 and 5.3. The median of the first item, peou1 ("Interaction with the app is clear and understandable"), is 6.0. The three other items, peou2 ("Interaction with the app does not require a lot of mental effort"), peou3 ("I find the app easy to use"), and peou4 ("I find it easy to get the app to do what I want it to do"), have a median of 5.0.

For perceived enjoyment the respondents in both surveys used a semantic differential with contrasting adjectives at each end to rate these items. The scale used in the street survey was a discrete scale with seven categories while the scale used in the web survey was continuous. The replies from the continuous scale were later on coded into seven categories.

Table 3 shows the descriptive results of responses on enjoyment.

Item	N	Min	Max	Mean	Median	Std. Deviation
pe1	200	1	7	6.06	7.0	1.562
pe2	200	1	7	5.60	6.5	1.881
pe3	200	1	7	6.17	7.0	1.514
pe4	200	1	7	5.67	7.0	1.993

Table 3: Statistical summary of web survey responses to items measuring perceived enjoyment

In the web-survey all the items have a mode of 7 and a mean in the range between 5.6 and 6.2. Furthermore, items pe1 (disgusting-enjoyable), pe3 (unpleasant-pleasant), and pe4 (boring-interesting) all have a median of 7.0. Item pe2 (dull-exciting) has a median of 6.5.

Table 4 shows the descriptive results of responses on intention to use.

As for intention to use, in the web-survey items bi3("I intend to use the app on a tablet") and bi4("I predict that I will use the app on a tablet") both have a mode of 4 and a median of 4.0. Furthermore, their means are close together with a value of 4.01 and 3.55. The means, medians and modes of the three other pairs of items are not so similar. Items bi1("I intend to use the app on a smart-phone") and bi2("I predict that I will use the app on a smart-phone") both have a mode of 4, but bi1 has a median of 5.0 and a mean of 4.58

Item	N	Min	Max	Mean	Median	Std. Deviation
bi1	200	1	7	4.58	5.0	1.760
bi2	200	1	7	4.07	4.0	1.700
bi3	200	1	7	4.01	4.0	1.779
bi4	200	1	7	3.55	4.0	1.695
bi5	200	1	7	5.05	5.0	1.577
bi6	200	1	7	4.45	5.0	1.692
bi7	200	1	7	4.54	5.0	1.779
bi8	200	1	7	4.16	4.0	1.810

Table 4: Statistical summary of web survey responses to items measuring behavioral intention

while bi2 has a median of 4.0 and a mean of 4.07. Items bi5("I intend to use the app in a city I visit as a tourist") and bi6("I predict that I will use the app in a city I visit as a tourist") both have a median of 5.0 but bi5 has a mode of 6 and a mean of 5.05 while bi6 has a mode of 4 and a mean of 4.45. Items bi7("I intend to use the app in my hometown") and bi8("I predict that I will use the app in my hometown") have two modes and two different medians, but the means 4.54 and 4.16 are closer together than the means of bi1 and bi2, or bi5 and bi6.

The survey were analyzed using the statistical software Smart PLS [34]. All four scales reached a composite reliability value of at least 0.90 and are thus well above the 0.70 threshold for composite reliability. They also showed high internal consistency with the lowest Cronbachs alpha being 0.88, well above the 0.70 threshold for confirmatory research. The lowest average variance extracted was AVE = 0.74, also above the suggested limit of 0.50. All the scales used in the web survey show strong convergent validity. The lowest of the outer model loadings is 0.79 (pe3 $\leftarrow$ PE). Furthermore, the t-statistics shows that all loadings are significant at the $p < 0.001$ level. The web survey measurement model meet the first criteria for discriminant validity. The cross loadings between measurement items and their theoretically assigned factor are consistently greater than the cross loadings between the measurement items and the other factors.

Figure 7 shows the structural model calculated with data from the web survey.

There are three pieces of information in the figure:

1. path coefficients
2. t-statistics showing levels of significance (in parentheses)
3. R^2 values (in the circles)

The structural model shows that all five hypotheses were supported. With the exception of the path between PEOU and BI, all paths were significant at the $p < 0.001$ level. The path between PEOU and BI were significant at the $p < 0.05$ level. The more tests performed on the same data set, the more likely it is that one will find significant results occurring by chance (what is called the problem of multiplicity [35]). To address this we have adjusted the α-values (the probability error rate, i.e. the probability of making at least one type I error, judging a relationship to be significant even if it is not) to make the tests more stringent in order to make allowance for such chance significant results. One possibility is to use the Bonferroni Adjustment in this case, which basically says that if you have, e.g. five test, you would need to adjust your significance-level from, e.g. 0.05 to 0.01 on all tests. The Bonferroni Adjustment is rather conservative, since it ignores the correlation between tests. Holm [16] suggests ordering the p-values of the K hypotheses as $p_1 \leq p_2 \leq \ldots \leq p_K$ and comparing to a pre-described α-level. Then one can show that a_i; for i = 1...K; must be set equal to α /(K -i+1).That means p_1, the smallest p-value must be compared with $\alpha_1 = \alpha/K$ (= 0,01 in our case) etc. up to p_K being compared with $\alpha_k = \alpha$ (=0,05 in our case). Thus even with this adjustment all relationships are significant at the $p < 0.05$ level.

Overall, the model explained about 57% of the variance in usage intentions.

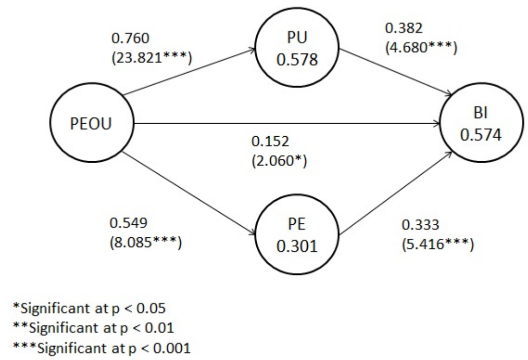

Figure 7: Structural model with data from the web survey

5.2 Results from the street-survey

In the street survey, the age-ranged was 14 to 60, with a mean age of 27.8. 59.5% of the respondents were male. About a fifth of the respondents replied that they had used a similar application.

Table 5 shows the descriptive results of responses on perceived usefulness.

Item	N	Min	Max	Mean	Median	Std. Deviation
pu1	42	4	7	6.00	6.0	0.963
pu2	42	4	7	6.38	6.0	0.661
pu3	42	4	7	6.24	6.0	0.726
pu4	42	3	7	6.05	6.0	0.963

Table 5: Statistical summary of street survey responses to items measuring perceived usefulness

On perceived usefulness, all four items achieved high scores and have a mean above 6, a median of 6 and a mode of 6 or 7. However, the responses to pu1 (“By using the app, I can more quickly and easily find historical pictures and information”) and pu4(“By using the app, I am more likely to find historical pictures and information that interests me”) are slightly less positive than the responses to pu2 (“By using the app, I learn more about history in Trondheim”) and pu3 (“By using the app, I can quickly find historical pictures and information from places nearby”).

Table 6 shows the descriptive results of responses on perceived ease of use.

Item	N	Min	Max	Mean	Median	Std. Deviation
peou1	42	3	7	5.52	6.0	1.215
peou2	42	3	7	5.88	6.0	0.993
peou3	42	4	7	5.79	6.0	1.001
peou4	42	4	7	5.57	6.0	1.016

Table 6: Statistical summary of street survey responses to items measuring perceived ease of use

The responses in the street-survey to the four items on perceived ease of use all have a median of 6.0. Item peou1 (“Interaction with the app is clear and understandable”) has the highest mode, with 7 being the most frequent response. At the same time, it has the lowest average score with a mean of 5.52. Items peou2 (“Interaction with the app does not require a lot of mental effort”), peou3 (“I find the app easy to use”), and peou4 (“I find it easy to get the app to do what I want it to do”) all have a mode of 6 and means between 5.5 and 5.9.

Table 7 shows the descriptive results of responses on perceived enjoyment.

Item	N	Min	Max	Mean	Median	Std. Deviation
pe1	40	3	7	5.83	6.0	1.130
pe2	40	3	7	5.45	5.0	1.131
pe3	40	4	7	5.70	6.0	1.067
pe4	40	3	7	6.00	6.0	1.038

Table 7: Statistical summary of street survey responses to items measuring perceived enjoyment

In the street-survey all the items: pe1 (disgusting-enjoyable), pe2 (dull-exciting), pe3 (unpleasant-pleasant), and pe4 (boring-interesting), have means that range between 5.5 and 6.0. Items pe1, pe3, and pe4 all have a median of 6.0 and at least one mode of 7 (item pe3 has two modes: one of 5 and one of 7). Item pe2 have a median of 5.0 and a mode of 5.

Table 8 shows the descriptive results of responses on intention to use.

Item	N	Min	Max	Mean	Median	Std. Deviation
bi1	40	3	7	5.98	6.0	1.121
bi2	41	3	7	5.80	6.0	1.229
bi3	41	2	7	5.22	5.0	1.557
bi4	42	1	7	4.81	5.0	1.784
bi5	42	4	7	6.45	7.0	0.889
bi6	42	3	7	6.12	6.0	1.109
bi7	42	1	7	5.43	5.0	1.548
bi8	42	1	7	5.24	5.0	1.620

Table 8: Statistical summary of street survey responses to items measuring behavioral intention

Intention to use is the only area in the street survey where the respondents have used the entire scale. The standard deviations range from a low of 0.889 to a high of 1.784.

All the items have at least one mode of 7. Items bi7(“I intend to use the app in my hometown”) and bi8(“I predict that I will use the app in my hometown”) have two modes, with the second one being 5. These two items also have a median of 5.0.

The medians and means of items bi5(“I intend to use the app in a city I visit as a tourist”) and bi6(“I predict that I will use the app in a city I visit as a tourist”) are noticeably higher than the medians and means of the other items. Item bi5 has the highest median and the highest mean of all the items in this scale. The values for bi6 are slightly lower but still higher than the other items.

Items bi1(“I intend to use the app on a smart-phone”) and bi2(“I predict that I will use the app on a smart-phone”) both have a median of 6.0. Their respective means are 5.98 and 5.80. These values are higher than the means and medians of items bi3(“I intend to use the app on a tablet”) and bi4(“I predict that I will use the app on a tablet”). Item bi3 has a mean of 5.22 while bi4 has a mean of 4.81. Both have a median of 5.0.

5.3 Discussion

We have proposed a research model and five research hypotheses that explain users’ adoption of mobile augmented reality applications with cultural heritage resources. Table 9 summarize the results from the hypothesis-testing based on the web survey.

	Estimate	Significance
H1 PEOU → BI	0.152	Significant at $p < 0.05$
H2 PU → BI	0.382	Significant at $p < 0.001$
H3 PEOU → PU	0.760	Significant at $p < 0.001$
H4 PEOU → PE	0.549	Significant at $p < 0.001$
H5 PE → BI	0.333	Significant at $p < 0.001$

Table 9: Summary of hypothesis test results

The technology acceptance model for hedonic systems was found to fit the data. The model was tested with the results from the web survey, and accounted for 57% of the total variance in intention to use. In comparison, van der Heijden was able to account for 35% of the variance in intention to use in his study, while Chesney accounted for 62% of the variance in his study [8, 39].

A large body of research have previously shown that perceived usefulness is the strongest predictor of user acceptance and that the effect of perceived enjoyment is consistently weaker then the effects of perceived usefulness and perceived ease of use [9, 18, 19]. However, in his study of user acceptance of a pleasure-oriented information system, van der Heijden [39] found that perceived enjoyment and perceived ease of use were stronger determinants of intention to use than perceived usefulness. Chesney [8] repeated this research with a dual system that were used for both utilitarian and hedonic purposes and found that perceived usefulness did achieve dominant predictive value over perceived enjoyment and perceived ease of use.

The results from this study indicates that mobile augmented reality applications with cultural heritage resources are dual in nature. People want to use this type of applications because they enjoy the experience, but also because it helps them achieve some (learning) goal. This also explain the difference between the intention to use the application as a tourist versus the intention to use the application in their hometown. As tourists, many people go on sightseeing and look at historical places. This type of application helps them do that. The users do not feel the same need in their hometown and are thus less interested in the application.

5.3.1 Practical Recommendations

The results of this study can benefit cultural heritage institutions that are considering developing a mobile augmented reality application. The technology acceptance model indicates how this type of application can be made more acceptable to users, while the comments and the different results between intention to use depending on context show the importance of selecting the right platform and aiming for the right user groups. This study showed that both perceived usefulness and perceived enjoyment had a strong positive effect on the intention to use this type of applications, and that they both achieved dominant predictive value over perceived ease of use. As a result, it is natural to focus on how to improve these two factors.

The participants in the street survey had several concrete suggestions for further improving the usefulness and enjoyment of the application. One of the participants suggested adding movies. Others suggested connecting the app to a larger existing tour guide or adding the ability to access ready-made tours. Another group of testers focused on the ability to personalize the application. It was also suggested to link the app to existing physical resources such as plates with historical information or buildings and walls engraved with years.

Perceived ease of use had less of a direct impact on intention to use than the other constructs, but played an important part in influencing perceived usefulness and enjoyment. Usability was the main focus under the initial development of the application and the replies to the items measuring perceived ease of use still indicates that there is room for improvement. However, the results are better than those achieved under the usability evaluation of the first version of the application. This show the importance of iterative development and evaluation with users as suggested by Nielsen [30], and Gould and Lewis [12].

The scores on the items measuring the intentions to use the application on a smart-phone were higher than the scores on the items measuring the intention to use the application on a tablet. It is not surprising that a smart-phone owners that do not have a tablet are less willing to use the application on a tablet. However, the tablet owners were also more negative to the tablet application and mentioned that it would be inconvenient to carry a tablet around downtown.

The participants in both surveys were more positive to using the application in a city they visited as a tourist than they were to using it in their hometown. This indicates that it may be an idea to target tourists as well as locals, and support multiple languages. One of the participants also suggested renting out devices with the application pre-installed.

Earlier applications in Trondheim of this sort has been based on a client-server model. To make it easier to maintain, this application was made as a stand-alone app, i.e. after installing the app there is no need to have contact with a server to get additional content. This has made it easier to deploy the application, but also means some limitations as for supporting data-updates and the possibility of dealing with e.g.movies and other more resource-demanding formats and techniques [23].

5.3.2 Limitations

There are some limitations of this study. One aspect is the different usage-modes in the web-survey (seeing a video exemplifying the use of the application) vs. testing the application out on site in practice. Whereas the first have acted primarily to check the research model as illustrated in Figure 7(i.e. the relationships between the different constructs), the input of the more high fidelity experiment on-site provides input on level of interest to use the application and more concrete input for additional features. The street survey participants were generally more positive about the application than their web survey counterparts, and this might be based on unwanted bias by presence of the investigator especially on testers without formal training.

The web survey participants rated the application higher on the scale for perceived enjoyment, but it is likely that this is due to the different format that was used for this scale in the web survey. The company that collected the data used a continuous slider to program this question instead of having seven different categories. The answers were afterwards mapped into seven categories. It is possible that this format encourages the respondents to use the endpoints of the scale. That would at least explain the high number of scores of 7.

The number of participants in the street survey was also rather small to do PLS-analysis. Due to this, we have used the web-survey to investigate the research model.

Another limitation of the study is the translation of the items (the questions were asked to Norwegians in Norwegian). This is especially clear in the scale measuring intention to use where the odd-numbered items start with “I intend to use...” while the even-numbered items start with “I predict that I will use...”. In both surveys, the responses to the even-numbered items are consistently lower than the responses to their odd-numbered counterparts. This is not a common trend in acceptance research. However, the comments from some of the street survey respondents provide an explanation for the difference. When answering whether they intended to use the application, they actually answered how much they wanted to use it. When answering whether they predicted they would use the application, they also considered external factors such as the fact that they did not own a tablet.

Finally the generalizability of the results can be questioned. As described above a similar application had earlier been made on a normal mobile platform with maps and geo-tagged historical pictures with limited success, not getting past the prototype stage. The similar application on a mobile augmented reality platform have received better feedback from testers and been released for general use. This mirrors the results reported in [4] claiming that providing AR experiences on mobile devices can have unique benefits over offering non-AR content on the same topic. Further investigations is needed to find out exactly what is the characteristics of a domain to see this effect. The investigation was performed in Trondheim, Norway. The area (and Norwegians in general) are known to quickly adopt new technologies. It is hard to judge if users in other countries where the use of smart-phones and tablets are not so wide-spread would be less positive to applications of this sort. Given that the application do not store any private data, aspects of trust that carry different weight in different cultures [10] would not be expected to influence the results.

6 Conclusion

This work has applied a technology acceptance model for hedonic systems to examine the determinants of intention to use a augmented reality application with historical information and pictures. A prototype application was built and used to demonstrate the concept for the participants in the street survey that was conducted as part of the project. The app has later been made available on appstore. A questionnaire was used for data collection. The same questionnaire was also used in the web-survey, conducted online. The participants in the web-survey watched a video-presentation of the use of the application to get an introduction to it before answering the questionnaire. A partial least square analysis was conducted on the data to estimate a structural equation model for the acceptance of this type of application.

The results show that both perceived enjoyment and perceived usefulness are important determinants of intention to use augmented reality application with historical information and pictures. This finding suggests that institutions developing this type of applications can benefit from focusing on both the fun and the usefulness of their applications. This can be compared with e.g. games, where the hedonic aspects would dominate, and a business application, where the focus would probably mainly be on the utilitarian aspects.

The concrete application is on the wish from the owners of the picture material being made generally available, and we will follow the experiences from actual usage to get ideas for improving the applications, and for input to other applications of this type. Extensions to provide support for user-generated content to this kind of solutions will also be looked into. We will also investigate a similar platform for other applications in the city such as more general learning services and mobile games, investigating how the results reported here can be generalized to other domains.

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