Learning by Imagining History: Staged Representations in Location-Based Augmented Reality

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Abstract. In the SPIRIT project, a location-based Augmented Reality (AR) application has been developed to stimulate the imagination of historical personal life at outdoor places. This paper presents quantitative evaluation results concerning the app's potential for educational purposes. They are based on 107 questionnaires filled by visitors of a Roman fort museum site, having used the AR app in a 40 min tour over several locations. At each place, users can turn into several directions and see keyed video representations of acting characters superimposed on their device's camera image. The fictional events are made up based on historical facts specific to the location. Next to issues with the novelty of the interaction, there has been an interrelation of the subjects self-assessed gaining of knowledge and the appreciation of the story's motivational factors.

Keywords: User experience evaluation · Location-based storytelling
Augmented Reality for cultural heritage education

1 Introduction

The application of location-based Augmented Reality (AR) systems in museums and at historical sites has been pursued since the technology has been available. While more often, real objects with attached marker symbols were simply superimposed with information [6, 11], only few examples exist in which live performances are visually blended within the experienced reality [12] without markers. This inevitably leads to novel user interaction patterns, which have been explored in our project 'SPIRIT'. In this paper, we present empirical evaluation results of our playable prototype running on tablets and smartphones, which has been used by regular visitors of an outdoor museum site, the Saalburg Roman fort. The AR app and content was built previously to enable the imagination of the life of typical fort inhabitants during the Roman occupation in Germany. This kind of storytelling of 'staged' events afforded a complex conception of weaving historical facts of this specific location into aspects of family entertainment and dramatic storytelling, as well as addressing still existing limitations of the used AR technology. For technical details, see [7] for the integration of GPS and

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markerless image recognition, as well as [10] for our plot engine parsing a formalised content structure (XML) to be authored by game designers, and [16] for the conception of sensor-based interaction patterns, pre-tested with users in about 20 formative evaluation cycles. The resulting prototype has been evaluated in spring 2017 during regular operations of the museum. 107 visitors filled questionnaires after using our tablets in a tour of about 30 to 40 min, being accompanied and observed by two researchers. In the following, we report on selected insights of the quantitative analysis, focusing on potential effects for learning and engagement with history.

2 Related Work

In our project, we created a novel complex interaction style and story format that we have not found elsewhere yet. We evaluated it with regular museum visitors, spanning a great diversity of people including families. The results therefore are unique, as for the most comparable found AR evaluations, subjects had been acquired in a more controlled way [6]. There is still a lack of evaluation in AR with non-technical target groups, as a majority of subjects used to be recruited within the academic field [2] or higher education settings [1].

Besides testing usability, the experience aspired by design relates most to the feeling of presence or sense of place. The latter have been evaluated [4, 14] with applications that so far do not resemble our integration of the search for places, turning around and rendering through video-based storytelling. Still, there are outcomes in line with those of our study, concerning the necessary distribution of attention focus between media and the environment. Recent evaluations addressed learning outcomes and experiential qualities [5, 13]. The results of these support our design goal to not focus on stories for the mere acquisition of knowledge, but for motivational aspects, such as gaining empathy with the past. Additionally, AR does not yet rely on standardized user interaction styles, as different hardware approaches lead to unfamiliar systems that have to be learned by novice users in the first place, which points back to requiring pre-existing motivation of users for success [3, 18].

3 Content and Interactive Experience

One of the first visions of this project, which was inspired by possibilities of location-based Augmented Reality, was to realize the metaphor of ‘meeting the spirits of history’ right where they lived their lives. As the goal was to achieve a feeling of presence of events and action at the historically relevant place, it was found important to tell a story that addresses emotions and imagination, rather than to report facts and numbers. The result of the conception, which included location scouting, historical research and hiring a skilled writer and director, contained several threads of information: (i) A fictional story thread of private love and family life, fitting historical

knowledge about the life of inhabitants of the Saalburg fort and associated village, (ii) another fictional story thread imagining events resulting from political relationships between the Roman emperors and the Germanic tribes, including corruption and assaults, and (iii) a list of facts that can be read alongside each fictional scene, backing up the fictional events by approved knowledge, according to the state of history research (Fig. 1, right).

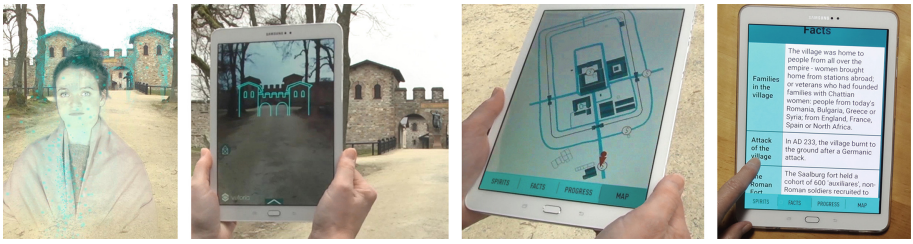

Fig. 1. Left to right: (a) Aurelia indicates the next place by a memory contour. (b) An equivalent memory stencil is used to align the tablet with the main gate. (c) The current GPS position is shown on the map. (d) Brief facts for each scene can be read on demand in a relaxed position.

A special user interaction pattern was conceived, with the goal to let users better experience the on-site reality in which the video representations are blended in. By prompting users to turn around and look into different directions in which scenes are deliberately integrated, the real locality plays an important role as historical setting. As side effect, due to the novel kind of interaction, users have to process more information by learning how to interact successfully. For simplicity and to avoid over-complex interactions in the first instance, the prototype tested worked with a linear story tour.

3.1 Content Description of the Evaluated Experience

The experience was evaluated with regular visitors of the Saalburg [15], a Roman fort partially reconstructed already by the turn of the century AD 1900 with an educational purpose. A brief tutorial explained the interaction with the app. Users follow memories of the spirit "Aurelia", who shows us visual schemes of places that have been meaningful for her. Users can use these as stencils to align the tablet camera to fitting backdrops, for example buildings, found in reality (see Fig. 1, left). Thus, matching background images trigger videos that let appear spirit characters as if seen through a window in reality (Fig. 2). They act out scenes while Aurelia narrates further happenings. Lateral arrows prompt users to turn the tablet 90 degrees to the left or to the right, triggering further 'spirits' in the space around, interacting with each other (see Fig. 2).

Fig. 2. One location with two viewing directions, experienced in a given sequence. (1) Right: To the right of the initial main gate view, two girls appear (in front of low-rise village ruins) with a piece of wood, asking Aurelia to read. (2) Left: Turning the tablet back to the gate after that scene, Aurelia and Aliquander decipher the cry for help from somebody kidnapped.

Aurelia's memories begin in her former village – now only visible as low-rise mural remains – outside the main gate of the Roman fort (Fig. 1, left). After a day of Germanic attacks, two girls – children of a veteran soldier – show her a piece of wood, which expresses a cry for help from a kidnapped cart (Fig. 2). Together with her friend Aliquander, with whom she seems to share neighborly friendship as well as a beginning romance, she follows the carriage. They find out that a Germanic ruler uses corrupt auxiliary soldiers to get hold of Roman weapons, only to beat the Romans with their own means. By finding more spirit-active locations through Aurelia's memory stencils and GPS navigation, we accompany her, sneaking into the fort to warn her father, the Centurion of the fort, in the central building called 'Principia'. When the Romans then try to stop the carriage at the eastern gate, they get into another attack. Here, Aurelia fears for Aliquander's life and realizes that she cannot imagine being without him. Back at the main gate, her memories reveal to the visitor that after this incident, they had married and started a family. With a happy end feeling, they died in their old age, long after the fort had been given up by the Roman Empire as a consequence of the attacks.

Many story events trigger notifications of the "Facts" menu, indicating that factual text information is associated. This can be accessed on demand from the menu, in between fictional scenes. For example, the village was indeed attacked in the year AD 233, and we learn details about the situation of women and private life during the Roman occupation (Fig. 1, right).

3.2 Constraints Influencing the User Experience

Spirits are only visible when the suitable events are triggered – by matching a given GPS position and backdrop image. The software searches all camera input for matching pixel patterns in a set of given reference images. The image recognition (described in [7]) works sufficiently reliable on visually significant buildings. However, on days with frequent weather changes, recognition might fail. Triggering new videos after turns to

the left or right is independent of visually significant backgrounds. It is accomplished by the gyroscope sensor, which works incrementally. For novice users, the proper momentum and degree of turning requires tutorial demonstration and some practice. After adopting the movement, it works reliably. The augmented content consists of video sequences with live-acting characters. As expected for AR content, these look like floating in thin air on top of the device's camera image of real surroundings. This is a crucial feature for the experience of presence, but nevertheless, it can lead novice users, who are inexperienced in AR, to miss the visualization when they move the tablet too fast, while the audio stream continues. Concluding, issues due to the technicalities of the prototype and the novel kind of interaction did partially influence the assessed user experience in our test.

3.3 Goals for the Experience and Learning Goals

Although the showcase is in the field of cultural heritage, the acquisition of reproducible factual history knowledge was not the main goal of its design. We wanted to create an imagination of people's personal lives by 'meeting the spirit of history' right at its (former) location. Therefore, the design avoided situations, in which characters also adopt the role of modern museum guides, narrating today's approved knowledge. Thus, explicit history 'learning' is voluntary and takes a back seat to experiencing. The goals we wanted to achieve with the specific AR app design have been (i) the experience of 'presence' of the spirits in the real environment, (ii) motivation and interest to learn more about the Roman world through an emotional story, and (iii) the freedom to access factual information from the menu at the individual user's convenience for appreciating the connection of the story's events to historical knowledge.

4 Empirical Analysis

4.1 Survey

The inquiry was carried out by students of RheinMain University of Applied Sciences, as a supervised learning project, on five days in May/June 2017 at the Saalburg Roman Fort [15]. The interviewers randomly invited regular museum visitors to participate in the testing and survey. 70 groups of visitors could be acquired to walk the tour with the app. Two researchers accompanied each tour, one for support and one observer of situational reactions. 107 subjects from these test groups completed the post-tour questionnaire and answered additional qualitative questions. The questionnaire included 26 groups of questions with 40 single questions, 20 of which were related to the broader subject of 'learning'. Before detailing the statistical analyses, we summarize interesting basic facts (see also Tables 1 and 2):

- Users rated the experience mainly positive (average grades of 4.0–3.8 on a 5-step Likert-Scale, where 5 is highest degree of approval) based on the questions "I had fun using the app", "I wish the app is available also in other museums with fitting content", "I recommend the app".

- 88.8% of the users reported disturbing factors while using the app. These were mainly caused by the queried items of (a) "holding the tablet" (2.8) and (b) "technical problems" (2.7).
- Regarding the questions (a) "I have gained knowledge of the Saalburg when using the app" and (b) "The app motivates me to now learn more about the Saalburg", the users expressed neutral up to rather positive opinions (average grades of 3.1 for (a), and 3.2 for (b)).
- Concerning parameters for the "motivation to continue", all items were ranked rather positive (queried items were "Search for locations" 3.8, "Novelty of the app usage" 3.7, "Suspense of the story" 3.2).

Despite several disturbing factors, the respondents estimate the usage and experience of the application mainly positive. The relationship between the age of the visitors and selected statements about the app is depicted in Tables 1 and 2.

Table 1. Age of visitors and app evaluation (average grades)

Age (years)	Frequency (Age)	App-Experience	Had Fun	Gained Knowledge	Motivated to continue by…		
					Suspense	Novelty	Search
< 20	31.8%	2.1	**4.4**	**3.7**	**3.8**	3.8	**4.3**
20-29	15.0%	3.0	3.3	2.2	2.5	3.3	3.8
30-39	12.1%	2.5	3.5	2.8	2.3	3.8	3.5
40-49	17.8%	1.8	4.2	3.4	3.2	3.4	3.4
50-59	16.8%	1.7	4.1	3.2	3.4	3.7	3.7
60+	6.5%	1.4	3.9	2.3	2.7	**4.0**	3.4
Total	**100.0%**	**2.1**	**4.0**	**3.1**	**3.2**	**3.7**	**3.8**

Younger app users (under 20 years) reported to have the most fun (average grades of 4.4 on a 5-step Likert-Scale) and to have gained the most knowledge (3.7). In contrast, subjects between 20 and 29 years reported to have the least fun (3.3) and to have gained the least knowledge (2.2). This group also reported to have the most experience (3.0 on the Likert scale), concerning the question "I have experience with similar apps (Pokémon Go, Ingress, Geocaching, AR)".

Concerning parameters for the motivation to continue, the "Search for locations" (4.3), and "Suspense of the story" (3.8) were ranked very high by younger people (under 20 years). We conclude that the story is particularly interesting for the younger target group. In contrast, the "Novelty of the App usage" was particularly motivating for senior subjects (4.0). This is likely to be due to the different pre-experiences and expectations of the different age groups. Consequently, particularly for children and teenagers, the application is a new interesting and motivating experience to gain insights and views about the life in the Roman Fort.

For the age group from 40 to 59, mean ratings of between 3.2 and 4.2 are achieved, which makes the app also suitable for this age group. Only for the age groups between 20 and 39, as well as 60+, the app achieved less good ratings, especially in the category "Gained Knowledge".

Table 2. Age of visitors and assessed disturbing factors (average grades, Likert scale)

Age (years)	Frequency (Age)	App-Experience	Disturbing factors while using the app…				
			Noise	Holding Tablet	Other Visitors	Missing Spirits	Technical
< 20	31.8%	2.1	2.0	**1.9**	**1.9**	2.0	2.1
20-29	15.0%	3.0	2.5	3.5	**1.9**	2.8	3.6
30-39	12.1%	2.5	2.2	3.0	2.1	2.6	3.2
40-49	17.8%	1.8	2.6	3.1	2.8	2.5	2.7
50-59	16.8%	1.7	2.5	2.6	1.6	2.1	2.7
60+	6.5%	1.4	2.3	**4.2**	2.0	2.3	2.1
Total	**100.0%**	**2.1**	**2.3**	**2.8**	**2.0**	**2.4**	**2.7**

The subjects were also asked to assess potential disturbing factors by a Likert scale (5 means highest disturbance). Results are listed in Table 2. In general, younger users felt less disturbed by interferences than older users. For the disturbing factors "(Environmental) Noise", "Holding (the) Tablet", "Missing Spirits" (which may be due to technicalities or user errors) and "Technical (Problems)", the average evaluation grades are the lowest in the age group under 20 years. Over 60-year-old users were particularly concerned about holding the tablet as a disturbing factor (average grade 4.2). Here, on the one hand, the lack of habit of this generation in dealing with tablets and, on the other hand, possibly age-related physical limitations are expressed.

Overall, the outlined results show that the evaluated app was particularly suitable for younger people (under 20 years of age), because they (a) had the most fun by using the app, (b) reported to have the greatest learning effect in the app, and (c) felt the least affected by external influences in the app. The elder age groups present more concerns and issues about the usage of the application, however, generally they also vote positively for the application.

4.2 Reliability and Validity

Accordingly to the measurement of reliability with Cronbach's Alpha, in Table 3 only questions related to "Fun/Recommendation", "Learning/Presence/Atmosphere" and "Motivation/Like" are considered as reliable [8]. This implies that only for these 3 topics, the (Cumulative) Variance can be explained by differences in the characteristic to be measured and not by measurement errors, and the results are free of random errors (i.e. the results are reproducible under the same conditions).

Table 3. Validity and Reliability Analysis

Questions related to…	KMO	Bartlett-Test	Cumulative Variance	Cronbach´s Alpha
Fun/Recommendation (a)	**0.652**	$p < 0.000$	**77.637%**	**0.856**
Disturbing Factors/Experience (b)	0.538	$p < 0.000$	**57.717%**	0.533
Learning (c)	0.539	$p < 0.000$	**70.876%**	0.552
Learning/Presence/Atmosphere (d)	**0.811**	$p < 0.000$	**59.429%**	**0.852**
Motivation/Appraisal (e)	**0.694**	$p < 0.000$	**60.093%**	**0.762**

Examples questions for the five topics in Table 3 are: (a) "I enjoyed using the app", (b) "The following factors bothered me while using the app", (c) "I have gained knowledge of the Saalburg when using the app" and "The app motivates me to now learn more about the Saalburg", (d) in addition to (c) "Through the app, I could immerse myself into the Saalburg's history", (e) "The following factors motivated me to continue (Story, Novelty, Search)".

Due to the measurement of the validity with the significant p-values ($p < 0.05$) in the Bartlett-Test and the values bigger than 0.6 in the Kaiser-Meyer-Olkin test (KMO), the concepts "Fun/Recommendation", "Learning/Presence/Atmosphere" and "Motivation/Appraisal" are valid [8, 9]. Validity refers to the consistency of an empirical measurement with a logical measurement concept. The two concepts ("Disturbing Factors/Experience" and "Learning"), which have not been considered as reliable before, did not create valid results as well. All groups of questions show cumulative variances which are noticeably higher than 50% [9]. This means that between 57.7% and 77.6% of the variances of the collected data can be explained.

4.3 Regression Analysis

For the sake of brevity and the target on learning, we focus in the following on one short regression analysis, which is performed for the dependent variable "I have gained knowledge of the Saalburg when using the app" (Table 4).

Table 4. Regression Analysis – Dependent Variable "I have gained knowledge of the Saalburg when using the app"

Independent Variables/Questions	Regression Coefficient	R-square
Motivation to learn more about Saalburg	0.636	31.6%
Having fun by using the app	0.599	24.4%
Motivation by suspense of the story	0.505	44.1%

The dependent variable "I have gained knowledge of the Saalburg when using the app" is

- significantly positive influenced by the variable "I was motivated by the app to learn more about the Saalburg" (coefficient 0.636, R-square 31.6%),
- significantly positive influenced by the variable "I had fun using the app" (coefficient 0.599, R-square 24.4%),
- significantly positive influenced by the variable "I was motivated to continue by the suspense of the story" (coefficient 0.505, R-square 44.1%).

All the regression coefficients exceed the desired 0.500 (which are classified as sufficient), therefore the values can be classified as sufficient [8, 9]. The R-squares between 24% and 44% show that descriptive variables reach a medium explanation rate.

This means, mainly due to the facts that users (a) have fun with the app and (b) get motivated by the app, they are open to for gaining knowledge about the history of the Saalburg Roman Fort.

4.4 Correlation Analysis

The correlation coefficient analysis determines the degree of the relationship between two individual variables. It is not, however, the degree of dependence, but the degree of the linear relationship/proportionality, which would identify a correlation of 1.000 as 'perfect' relationship. Between the relevant 23 variables/questions, 253 correlation coefficients exist. We identified 65 correlation coefficients which are significant ($p < 0.050$) and have a value over 0.500 (which describes a good relation). For the sake of brevity, we focus on the relationships with correlation coefficients higher than 0.700:

- Relation between variables "I wish the app is available also in other museums with fitting content" and "I recommend the app": (coefficient 0.765), which is almost self-evident.
- Relation between the variables "I was motivated to continue by the suspense of the story" and "I liked the story": (coefficient 0.755), which supports strongly the results of the regression analysis.
- Relation between the variables "I enjoyed using the app" and "All in all, I rate the app concept …": (coefficient 0.718), which shows, that the overall rating of the app is strongly related to the 'fun factor'.
- Relation between the variables "I gained knowledge of the Saalburg through using the app" and "I liked the story": (coefficient 0.708), which shows that the gaining of knowledge is strongly related to the level of appraisal of the story.

5 Conclusion

Within the SPIRIT project, we developed a system and prototypical content for a specialized form of location-based interactive storytelling with Augmented Reality, to support implicit learning by imagining lively events in historical environments. The prototype has been evaluated with end-users concerning some special design goals connected to the AR experience, amongst others, the feeling the presence, as well as the relationship of AR dramatic storytelling with learning.

Based on the quantitative evaluation we found that overall, users liked the app and would recommend it. However, when asked, most users also reported some disturbing factors interfering with their usage, of which some were due to the prototypical nature of the app, but others will most likely remain also in more mature states. In particular, some users (especially seniors) had problems with "Holding the tablet". Younger users felt least affected by external influences. The regression analysis suggests that (a) the parameters "Motivation to learn more about the Saalburg", (b) "Having fun by using the app" and (c) "Motivation by suspense of the story" all have strong influence (regression coefficients: (a) = 0.636, (b) = 0.599, (c) = 0.505) on the extent to which users reported to have gained knowledge of the Saalburg when using the app.

Our learning goal of getting people motivated has yet been achieved mainly for the younger generation. This aspect is under further investigation in the qualitative part of the evaluation.

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