AR Sightseeing: Comparing Information Placements at Outdoor Historical Heritage Sites using Augmented Reality

ANDRII MATVIIENKO, Technical University of Darmstadt, Germany
SEBASTIAN GÜNTHER, Technical University of Darmstadt, Germany
SEBASTIAN RITZENHOFEN, Technical University of Darmstadt, Germany
MAX MÜHLHÄUSER, Technical University of Darmstadt, Germany

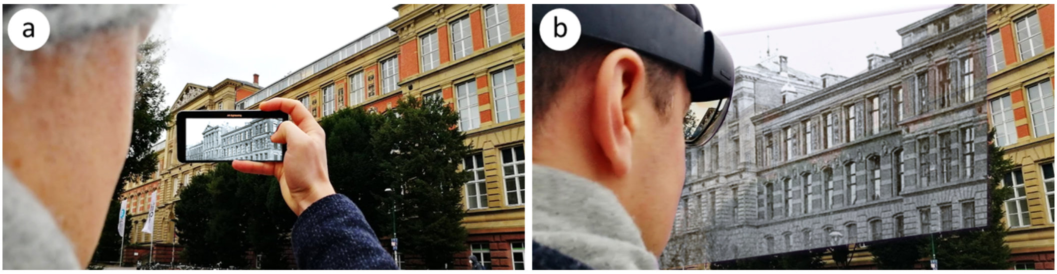

Fig. 1. A participant is using the (a) smartphone and (b) Augmented Reality glasses to explore an outdoor historical heritage site with an overlay image placement on top of the old building.

Augmented Reality (AR) has influenced the presentation of historical information to tourists and museum visitors by making the information more immersive and engaging. Since smartphones and AR glasses are the primary devices to present AR information to users, it is essential to understand how the information about a historical site can be presented effectively and what type of device is best suited for information placements. In this paper, we investigate the placement of two types of content, historical images and informational text, for smartphones and AR glasses in the context of outdoor historical sites. For this, we explore three types of placements: (1) on-body, (2) world, and (3) overlay. To evaluate all nine combinations of text and image placements for smartphone and AR glasses, we conducted a controlled experiment (N = 18) at outdoor historical landmarks. We discovered that on-body image and text placements were the most convenient compared to overlay and world for both devices. Furthermore, participants found themselves more successful in exploring historical sites using a smartphone than AR glasses. Although interaction with a smartphone was more convenient, participants found exploring AR content using AR glasses more fun.

CCS Concepts: • **Human-centered computing** → **Interactive systems and tools**; **Mixed / augmented reality**.

Additional Key Words and Phrases: sightseeing, augmented reality, historical heritage, information placement

Authors' addresses: Andrii Matviienko, matviienko@tk.tu-darmstadt.de, Technical University of Darmstadt, Darmstadt, Germany; Sebastian Günther, guenther@tk.tu-darmstadt.de, Technical University of Darmstadt, Darmstadt, Germany; Sebastian Ritzenhofen, sebastian.ritzenhofen@stud.tu-darmstadt.de, Technical University of Darmstadt, Darmstadt, Germany; Max Mühlhäuser, max@tk.tu-darmstadt.de, Technical University of Darmstadt, Darmstadt, Germany.

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1 INTRODUCTION

Since the advent of smartphones, augmented reality (AR) has influenced the way historical information is presented to tourists and museum visitors. On the one hand, AR helps tourism organizations and professionals reach a wider audience by creating immersive experiences with engaging multimedia content and mobile technology, which in turn increases interest in history [9, 26, 31, 35, 37]. On the other hand, AR offers tourists the opportunity to interact with historical heritages digitally, which enhances their experience and learning [7, 10, 16, 22]. Compared to physical, printed information boards, AR reduces the cost and effort of changing information at sites, provides users with "unlimited" digital content, generates positive experiences and word-of-mouth, and offers the opportunity to share visitors' experiences through an online community [1]. Moreover, historical sites can be immersively experienced again and damaged objects "repaired" or even "reconstructed" by augmenting physical objects with virtual parts. However, to create an optimal user experience when exploring digital content of historic sites, empirical research is still lacking the following aspects: (1) how to properly place augmented digital content on top of or close to the physical object and (2) which devices provide the best and most convenient interaction.

Previous research introduced numerous advanced techniques to augment digital content with images and texts, which included context awareness relevant to the user's task [33], personalized filters based on the user's interests and preferences [24], and dynamic presentation of information retrieved from online sources [27], e.g., Linked Open Data [1]. However, traditional information representation in AR for sightseeing is still in its infancy and primarily employs smartphones as powerful platforms for visualizing additional information. However, with the advent of consumer-oriented and low-cost wearables, AR glasses offer new possibilities for even more immersive and hands-free interaction through a larger field-of-view compared to smartphones. Therefore, it is essential to understand how the information about a historical site can be presented effectively to users and what type of device is best suited for which type of information placement.

In this paper, we investigate the placement of two types of content, historical images and informational text, for smartphones and AR glasses in the context of outdoor historical sites. For this, we explore three types of placements: (1) **on-body** – the content is anchored to the body of a user, (2) **world** – the content is anchored next to the object in the real world, and (3) **overlay** – the content is anchored "on top" of a physical object in the real world. To evaluate all nine combinations of text and image placements for two devices, **smartphone** and **AR glasses**, we conducted a controlled experiment (N = 18) at outdoor historical landmarks in Darmstadt, Germany (Figure 1). As part of our results, we discovered that on-body image and text placements were the most convenient compared to overlay and world for both devices. Interestingly, our results have also indicated that participants found themselves more successful in exploring historical sites using a smartphone than AR glasses. Finally, participants reported that exploring AR content using AR glasses was more fun with both hands being free, but interaction with a smartphone was more convenient.

[1] https://lod-cloud.net/

2 RELATED WORK

Existing augmented reality (AR) applications for historical heritage research have mainly focused on contextualizing historical environments based on user location and behavior, virtual reconstruction of historical artifacts and events using digital overlays and storytelling, and travel guides [6]. In this section, we provide an overview of previous work in these areas.

2.1 Context and Digital Overlay for Historical Heritage using Augmented Reality

Introduction of contextual mappings and digital overlay of historical information made it possible to shift the focus of cultural institutions to their visitors rather than their cultural heritage, which is known as a visitor-centric approach [17, 19]. We outline both concepts in the following.

2.1.1 Contextual Visualizations. One of the most important aspects of mobile augmented reality applications is the use of context awareness to display information to users. Context-aware visualizations ensure the display of information relevant to users' location [33] and behavior [28]. For example, to provide visitors with appropriate content, ArtScene [10] estimates user attention based on the collection and analysis of data streams, which facilitates the presentation of information depending on the physiological state of users. The ARCAMA [2] project incorporates the user's context via location and direction, which can filter relevant information according to the user's expectations and interests. Kourouthanassis et al. [27] used dynamic adaptation for the mobile application CorfuAR, which automatically filters content based on the user profile and contextual data. Another project by Quattrini et al. [30] explored the use of the user's location to retrieve contextual information and present an appropriate 3D model for historical architecture.

2.1.2 Digital Overlay. So far, researchers have used AR mostly for mapping and projecting documented information directly onto the object to avoid visual switching between the real structure and the information [2] [5, 8]. Battini & Landi [4], for example, have presented a mobile AR application that allows interaction with multiple layers of information superimposed on the 3D reconstruction of Leondardo da Vinci's Scala. Another project [5] presented a translucent AR system that projects contextual information onto physical objects, adding new digital information. Similarly, Vanoni et al. [36] developed ARtifact to augment physical artifacts with diagnostic images and data to improve the analysis process during conservation work. Given the success of the digital overlay shown in previous works, we build on the idea of overlay for placements of texts and images during sightseeing using AR.

2.2 Interaction with Historical Heritage in Augmented Reality

Cultural institutions, such as museums, libraries, galleries, and archives, tend to incorporate new interaction methods to enhance the user experience, such as mobile guides [25], AR augmentation of physical artifacts [36], and storytelling [14, 18, 29]. These methods include personalized user experiences that address user needs and digital storytelling that brings exhibitions "to life" through "speaking" and "interaction" with visitors. In the following we present examples from both groups.

2.2.1 Personalized Interaction. Personalized content is a requirement for all mobile applications today. The personalization process differs from context-aware computing in that it is usually completed in the first phase of initialization, when the user specifies his profile and preferences (or allows automatic extraction). Typically, personalization is coupled with context-aware computing and categorizes the user based on parameters such as age, personal interests, and education. For example, Keil et al. [23] presented CHESS as a personalized application with interactive storytelling

[2] https://www.future-history.eu/de

support based on the user profile. To stimulate visitors' learning motivation, Tan & Duh [21] introduced AR-based personalized learning patterns for Cantonese porcelain following the four phases of Kolb's experimental learning cycle [12]: concrete experience, reflective observation, abstract conceptualization, and active experimentation. In the aforementioned CorfuAR, Kourouthanassis et al. [27] offer visitors a choice between a personalized and a non-personalized version of the AR application. The given user preferences are extrapolated based on recommendations from the World Tourism Organization and improve user interaction. Another project called DynaMus [25] involves intelligent virtual agents that enable personalized visits and user-predefined tours to create a personalized experience for the user. Keil et al. [24] also introduced a new technique to filter digital information based on the user's movements by visualizing an object of interest with a circle in the center of the screen.

2.2.2 Interaction through Digital Storytelling. One of the most interesting approaches to digital storytelling was realized as part of the CHESS project for the Acropolis Museum. This project explores the use of personalized interactive storytelling embedded in the museum's artifacts. The stories are initially tailored to predefined profiles, but then adapt to the visitor's behavior and deliver different versions of AR activities that are dynamically integrated into the narrative. In a museum project called SVEVO, AR storytelling was coupled to a physical environment, but instead of considering the environment as a fixed default, it allows exploration of the mutual relationships between the interactive media and the environment [14]. The i-Wall presented by Gkiti et al. [18] involves visitors in an interactive experience of storytelling in an industrial museum on Syros Island. It facilitates interaction with touch sensors on an interactive wall that projects animations about electric vehicles. Spierling et al. [32] presented the SPIRIT research project, which uses location-based AR storytelling to support the imagination of historical events in culturally significant places. In the TAG CLOUD project, Perez et al [11] explored AR for personalized experiences based on context and user profile to provide adaptive experiences for each user. In this paper, we employ the idea of context-aware computing to automatically recognize historical sights and display virtual objects to users when they point their smartphones and AR glasses at objects.

2.3 AR Travel Guides

With the development of smartphones, it became possible to determine the user's position and direction of movement to facilitate real-time pedestrian navigation. However, the connection between digital information displayed on the screen and objects in the real world is often unclear and misleading, making it difficult to find interesting objects in the real world. To overcome this obstacle, Google has used augmented reality (AR) to provide navigation instructions in the real world with a connection to real objects. Live View allows users to open a camera view that merges location with navigation instructions, making it easier for them to find the object they want. The HoloMaps [3] app displays 3D map sections of a destination in Microsoft HoloLens and shows additional information about the current map section, such as the weather. Another example of the use of AR navigation is the identification of mountain peaks using a smartphone, e.g. PeakFinder [4]. Through a camera view, the user can explore the names of mountain peaks, which are displayed as an overlay over the mountains. Dünser et al. [13] took a step further and explored the affordances and limitations of currently available handheld AR browsers to navigation with a digital map and a combination of map and AR. They discovered that a combination of both map and AR was the most preferred method.

[3] https://taqtile.com/holomaps/
[4] https://www.peakfinder.org/mobile/

Classic travel guides are usually small books with sightseeing recommendations that provide background information about interesting objects. However, similar to smartphone applications, paper travel guides lack a connection to real historical objects. To better connect to real-world objects, the AR application Wikitude World Browser [5] recognizes places based on information about global points of interest, e.g. tourist attractions, restaurants. To do this, a camera view opens and the user points their smartphone at the relevant location and is then shown the relevant information from Wikipedia. A similar approach is taken by the Speicherstadt Digital App [6], which refers to a selected part of the city. At selected points, real buildings can be overlaid with historical views and background text can be superimposed on the smartphone display when the user taps a designated button. As part of the Story of the Forest project [7], the National Museum of Singapore provides an AR app that allows visitors to learn about local forests, which are displayed in real time on large screens. Certain elements of these images can be overlaid with information about the animals that live there and users are free to move around the exhibition spaces. Kourouthanassis et al. [27] empirically investigated a mobile AR travel guide to support personalized content provision and navigation features for tourists on the move. They reported that mobile Augmented Reality travel guides increase user satisfaction and usage intention.

Our work focuses on sightseeing using Augmented Reality rather than navigation instructions guiding users to a particular point of interest. Therefore, in contrast to previous work, we investigate how the information about historical sites can be presented to users effectively in terms of convenience of use, intuitiveness, and success of exploration, and which AR-capable device is most suitable for this.

3 AUGMENTING HISTORICAL HERITAGE SITES

Historical information can be presented using a variety of media, including text, audio, images, or even video. While the auditory content is independent of the visual channel, virtual labels can be used to display texts, images, or even videos. Texts typically provide historical information and more importantly convey background knowledge. Images and videos, on the other hand, illustrate what the heritage site looked like in the past. After the introduction of Augmented Reality (AR) technology, it became possible to show these kinds of visual content at any point in the surrounding environment, typically on top of the real-world surroundings as a semi-transparent layer. In particular, Azuma [3] defined AR so that it (1) combines the real and virtual world, (2) is interactive in real-time, and (3) is anchored to the real world. For example, multimedia content similar to traditional information boards could appear next to an object, be placed directly above an object, or even feel like a virtual manual in the user's hand. However, it remains unclear which of these placement for visual content at historical heritage sites are the most suitable.

In this paper, we investigate placements of visual content at historical heritage sites and attempt to combine the benefits of text and images with an association to historical context using augmented reality (AR). AR facilitates the anchoring of objects in the real world, allowing tourists to interactively explore an object of interest. However, it is unclear how text and images associated with objects of interest should be placed in relation to historical objects to enable convenient, intuitive, and entertaining exploration of a historical scene. For this reason, we conducted an outdoor experiment in which we explored different combinations of text and image placement, which we describe in the following section.

[5] https://www.wikitude.com/showcase/
[6] https://artsandculture.google.com/partner/speicherstadt-digital
[7] https://www.nhb.gov.sg/nationalmuseum/our-exhibitions/exhibition-list/story-of-the-forest

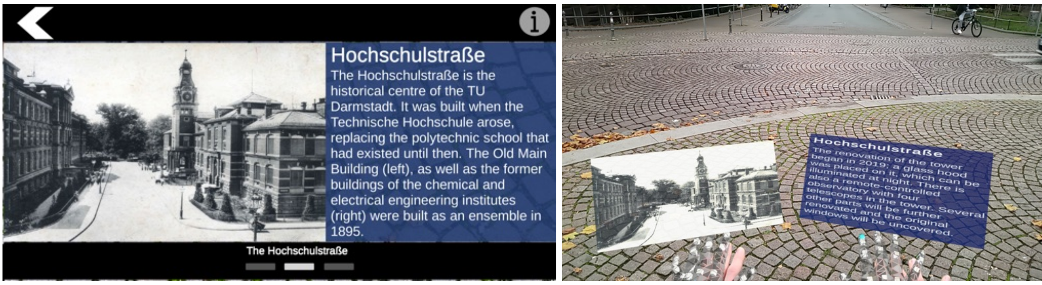

Fig. 2. On-body Placement for the smartphone (left) and the AR glasses (right).The on-body placement with a smartphone facilitates presentation of information directly in the smartphone application hold in the hands of users and AR glasses utilizes mapping of images and texts to users' hands.

4 EVALUATION

To investigate the convenience for different image and text placements and suitability of portable devices for sightseeing using Augmented Reality, we conducted an outdoor controlled experiment using AR glasses and a smartphone.

4.1 Participants

We recruited 18 participants (7 female and 11 male) aged between 21 and 35 ($M = 27.6, SD = 4.5$). Two of them were proficient AR users, nine had no experience at all, and the remaining seven participants used it sometimes. Most participants (N = 12) have participated in a regular guided tour (with a personal guide) up to five times, five of them more than five times, and one participant has never participated in a guided tour. Further, four participants never used an audio-supported tour guide and one third of the participants had experience with smartphone-based tour guides. All participants received no compensation for taking part.

4.2 Study Design

The study was designed to be within-subject with three independent variables: (1) image placement, (2) text placement and (3) device. For both, image and text placements, we explored three locations: (1) *on-body* – information is anchored on the body (Figure 2), (2) *world* – information is placed directly in the real world (Figure 3) and (3) *overlay* with an object in the real world (Figure 4). For the anchored on-body placement, the information for the smartphone was fixed on the screen independent from orientation and environment while the phone was held in the hand, and for the AR glasses it was anchored directly to the users' hands. Moreover, due to the nature of the AR glasses, the visualizations were always slightly transparent so that one could see both the historical image and the building behind it.

As for the device, we investigated the aforementioned image and text placements using two devices: (1) AR glasses and (2) smartphone. The main objective for comparing these devices is the difference in interaction, user experience, and common availability. For example, users can freely move a smartphone around to bring the elements into focus, but with the AR glasses they have to turn their head to the left and right to see the virtual content. With this, the on-body placement for the mobile phone exploration plays a vital role as a baseline since it represents the commonly used setup for digital information retrieval on the go. Furthermore, it meets the definition of on-body as the phone is kept in the user's hand close to the body, i.e., it represents a single still image on the smartphone's screen. In contrast, the on-body placement for AR glasses utilizes hand recognition. It anchors images and texts directly to the hands of users, similarly to on-body projections in which

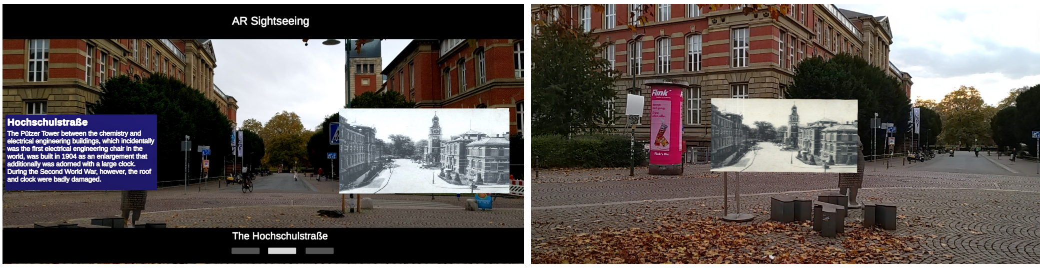

Fig. 3. World placements for the smartphone (left) and the AR glasses (right). The left image illustrates the image and text augmentations anchored to the world location near the historic building. Similarly, the image augmentation is placed near the historic building shown through AR glasses on the right.

the body acts as a canvas [15, 20]. As for the world placement, texts and images were anchored in a specific place next to objects of interest for smartphones and AR glasses. Finally, the overlay visualization employed real-time recognition of historical buildings and anchored virtual objects directly onto them. With this combination of different placements, we aimed to systematically explore different types of AR interaction techniques, which follow the definition of AR introduced by Azuma [3].

The combination of all image and text placements led to nine experimental conditions, which were explored with both devices (3 x 3 x 2 = 18 conditions). The order of the experimental conditions was counterbalanced using a Balanced Latin Square. Participants' task was to walk around a university campus and spot the historical objects of interest.

4.2.1 Historical Sites. For our experiment, we selected three different historical sites. All are historic parts of the university campus in the old town area of Darmstadt, Germany. All of the sites were within walking distance and had to be visited six times. While the images remained unchanged, different informational texts were presented to participants at revisited sights. The first site was the old power plant of the university that has been remodeled to serve as lecture hall and seminar rooms, the second was the university's old main building, and the third was a view into the ensemble of buildings of the old main building and the former chemical and electrical engineering institutes.

4.3 Apparatus

For experimental conditions with AR glasses, we used Microsoft HoloLens 2 Augmented reality headset [8], and a Nexus Pixel 4 for a smartphone. The study applications for the AR glasses and smartphone were implemented using the Unity game engine. Further, we used Vuforia together with the GPS location for tracking the environment to place the virtual images and text overlays on the correct positions. After the current participant has been selected, the smartphone can be pointed at the first test site. The location is then recognized by the image recognition and text and image objects are displayed at the positions, as configured in the CSV file. The image recognition was based on the Vuforia library [9], which facilitates recognition of feature points and tracks a given image in the actual environment. If the image recognition does not work, the virtual objects can also be displayed by the push of a button.

[8] https://www.microsoft.com/en-us/hololens
[9] https://www.ptc.com/en/products/vuforia

4.4 Measurements

To investigate the suitability and convenience for using proposed layouts with AR glasses and smartphone, we measured the following dependent variables:

- *Convenience of use*: for every condition, we asked participants to assess how convenient they found a combination of image and text placement for AR glasses and smartphone using a 5-point scale (1 – very inconvenient, 5 – very convenient).
- *Layout intuitiveness*: for every condition, we asked participants to assess how intuitive they found a layout of an interface using a 5-point scale (1 – very non-intuitive, 5 – very intuitive).
- *Success of scene exploration*: for every condition, we asked participants to indicate how successful they were in exploring a scene using a 5-point scale (1 – very unsuccessful, 5 – very successful).

Within the scope of this paper, we focused on the subjective measures of the proposed text and image placements. With this, we aimed to explore a close-to-reality scenario where users can freely experience historical sights without feeling time pressure or answer a series of questions to reflect their understanding and learning to avoid an increased stress level, i.e., an exam experience. Therefore, we utilized questions based on the Likert scale to understand better the convenience, intuitiveness, and how successful the users can be in exploring historical sights as essential aspects of user experience.

4.5 Procedure

After obtaining informed consent, we collected participants' demographic data. Afterwards we provided a brief overview of the procedures, which included explanations of all types of image and text placements. Participants familiarized themselves with both devices and visualizations during a short test prior to the experiment. Once the participants felt comfortable, we started experimental conditions. During the experiment participants had to walk around an area with historic buildings located at the University campus of Technical University of Darmstadt and point at points of interest using AR glasses or a smartphone, depending on the experimental condition. At the end of the study, we interviewed the participants about their preferences for the different placements for text and images, as well as interaction with the devices. The entire study lasted approximately one hour and was approved by the ethical review board of our university. Further, for this study we adhered to our universities health department's guidelines for user studies during the COVID-19 pandemic. All testing equipment was disinfected between participants and the study was conducted outdoors in the fresh air.

4.6 Data analysis

We tested the data for normality using Shapiro-Wilk's test. Given that collected data was not normally distributed, we applied the aligned rank transform for non-parametric factorial analyses [38]. We used pairwise t-tests with Bonferroni correction for post-hoc analysis when the RM ANOVA indicated significant results. To analyze the qualitative data, we followed the General Inductive Approach proposed by Thomas [34]. For this, we summarized raw textual data into a condensed format, created categories and subcategories to structure raw textual data and create links to research objectives, and developed the underlying structure of experiences evident in the raw data.

5 RESULTS

We discovered that participants found on-body image and text placements more convenient than overlay and world for both devices. However, we did not observe differences in terms of intuitiveness

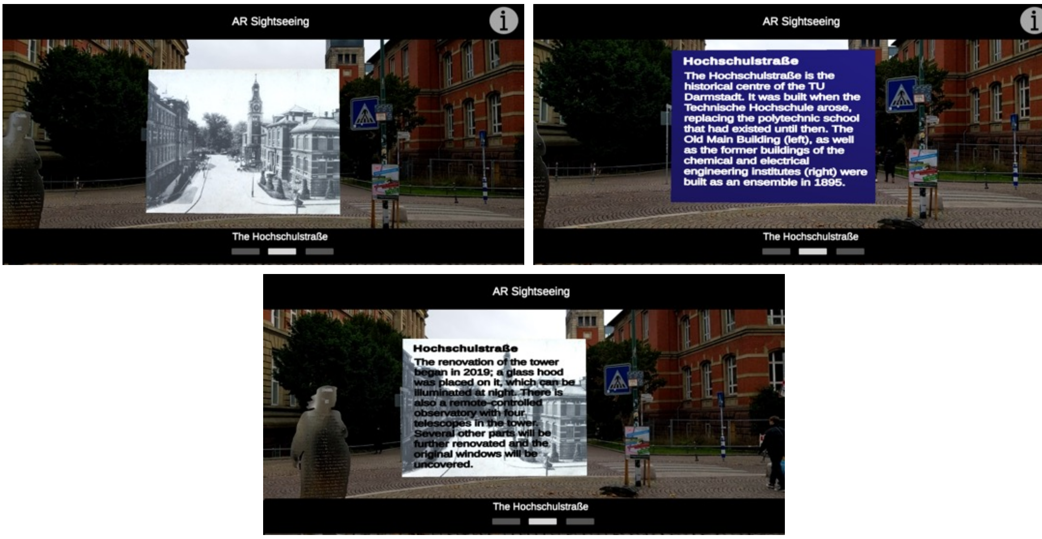

Fig. 4. Overlay placements for the smartphone, which looked identical for the AR glasses: (a) illustrates an image overlay and the text is shown after pressing an "i" button, (b) illustrates an text overlay and the image is shown after pressing an "i" button, and (c) combines image and text into one overlay. The overlay placement on AR glasses was slightly transparent, given the AR presentation on Microsoft HoloLens 2.

for devices, all text and image placements. Additionally, we discovered that participants found themselves more successful in exploring historical sites using a smartphone than AR glasses. Furthermore, participants reported that exploring AR content using AR glasses was more fun with both hands being free, but interaction with a smartphone was more convenient. We outline these findings in detail in the following.

5.1 Convenience

We discovered that participants found image placement on-body the most convenient ($Md = 4, IQR = 2$), followed by world ($Md = 3, IQR = 2$) and overlay ($Md = 3, IQR = 2$). This finding was supported by the statistically significant main effect for the image placement ($F(2, 34) = 12.9, p < 0.001$). The post-hoc analyses have further shown that on-body image placement was more convenient than in the world ($p < 0.001$) and with overlay ($p < 0.001$). However, we did not find statistically significant differences between image placement in the world and the overlay ($p > 0.05$).

Similarly, we discovered that participants found on-body text placement the most convenient ($Md = 4, IQR = 2$), followed by world ($Md = 4, IQR = 1$) and overlay ($Md = 3, IQR = 1$). This finding was supported by the statistically significant main effect for the text placement ($F(2, 34) = 29.8, p < 0.001$). The post-hoc analyses have further shown that on-body text placement is more convenient than world ($p < 0.05$) and overlay ($p < 0.001$) placements. Moreover, the world placement was found to be more convenient than overlay ($p < 0.001$). The main effect for the type of the device was not statistically significant ($p > 0.05$).

Furthermore, we observed two statistically significant interaction effects for type of device * text placement ($F(2, 34) = 3.39, p < 0.05$) and image placement * text placement ($F(4, 68) = 11.64, p < 0.001$). The first interaction effect indicated that on-body text placement using AR glasses was perceived more convenient than text overlay using a smartphone ($p < 0.05$). The second interaction

	Convenience		Intuitiveness		Exploration	
Image and Text Placements	Md	IQR	Md	IQR	Md	IQR
Text World	4	1	4	2	5	1
Text Overlay	3	1	4	2	4.5	1
Text On-Body	4	2	4	1	5	1
Image World	3	2	4	2	5	1
Image Overlay	3	2	4	1	4	1
Image On-Body	4	2	4	2	5	1

Table 1. Results of the subjective feedback using 5 -point Likert scales. Md = median, IQR = interquartile range, Lin. = Linear, Par. = Parabolic, Inst. = Instant, Inter. = Interpolated, Cont. = Continuous.

effect have shown that a combination of on-body image and text placements was found to be more convenient than image + text overlay ($p < 0.05$), image world + text overlay ($p < 0.001$), image overlay + text world ($p0 < 0.05$), except for the combination of image + text world, which was not statistically significant ($p > 0.05$). Additionally, it has shown that on-body image + overlay text was perceived more convenient than image overlay + world text ($p < 0.001$), but it was comparably convenient for image + text world combination ($p > 0.05$). Furthermore, a combination of image overlay and on-body text was perceived more convenient than world image and overlay text ($p < 0.001$), but it was comparably convenient with image + text in world. Lastly, we discovered that image + text in world is more convenient than image + text overlay ($p < 0.001$).

5.2 Intuitiveness

We discovered a comparable level of intuitiveness among both devices, all image and text placements. All image and text placements received a high score for intuitiveness: text world ($Md = 4, IQR = 2$), text overlay ($Md = 4, IQR = 2$), text on-body ($Md = 4, IQR = 1$), image world ($Md = 4, IQR = 2$), image overlay ($Md = 4, IQR = 1$), and image on-body ($Md = 4, IQR = 2$). The main effects for all three independent variables were not statistically significant: type of a device ($F(1, 17) = 0.52, p > 0.05$), image placement ($F(2, 34) = 1.57, p > 0.05$), and text placement ($F(2, 34) = 1.51, p > 0.05$). There were no statistically significant interaction effects for the types of devices, image and text placements ($p > 0.05$).

5.3 Scene Exploration

We discovered that participants found themselves more successful in exploring historical sites using a smartphone ($Md = 5, IQR = 1$) than AR glasses ($Md = 5, IQR = 1$). This finding was supported by statistically significant main effects for the type of device ($F(1, 17) = 26.1, p < 0.001$), As for the image placement, we discovered that on-body ($Md = 5, IQR = 1$) and in world ($Md = 5, IQR = 1$) image placements led to a more successful scene exploration than the overlay ($Md = 4, IQR = 1$). This finding was supported by a statistically significant main effect for the image placement ($F(2, 34) = 16.7, p < 0.001$). The post-hoc analyses have shown that the overlay image placement leads to less successful scene exploration compared to on-body ($p < 0.001$) and in world ($p < 0.001$) placements. However, we did not observe statistically significant differences between on-body and world image placements ($p > 0.05$). Similarly to the image placement, the text placement on-body ($Md = 5, IQR = 1$) and in the world ($Md = 5, IQR = 1$) led to a more successful scene exploration than with overlay ($Md = 4.5, IQR = 1$). This finding was supported by a statistically significant main effect for the text placement ($F(2, 34) = 24.4, p < 0.001$). The post-hoc analyses have shown that the overlay text placement leads to less successful scene exploration compared to

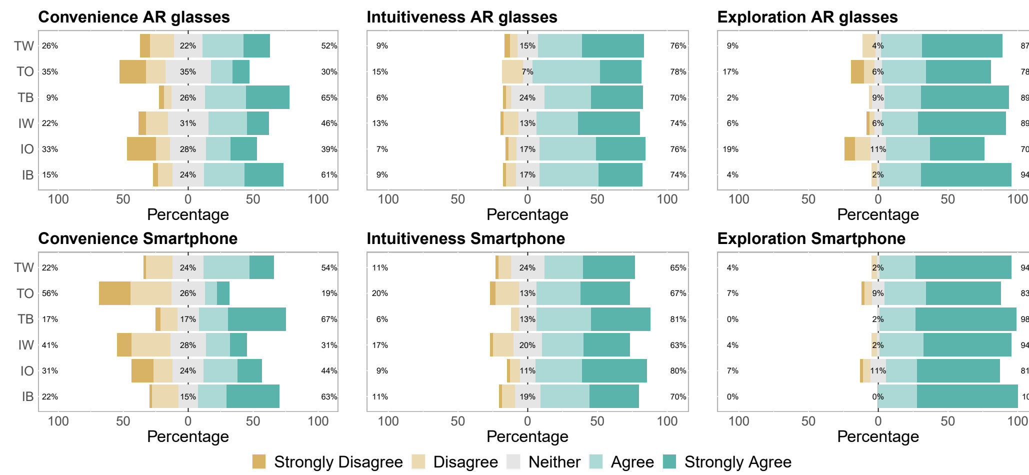

Fig. 5. Overview of Likert data for each question split by a type of device: convenience of use, intuitiveness, and assistance by scene exploration. TW/IW = text/image world, TO/IO = text/image overlay, TB/IB = text/image on-body.

on-body ($p < 0.001$) and in world ($p < 0.001$). However, we did not observe statistically significant differences between on-body and world text placements ($p > 0.05$).

As for the interaction effects, we discovered two statistically significant interaction effects: (1) type of device * image placement ($F(2, 34) = 9.45, p < 0.001$) and (2) image placement * text placement ($F(4, 68) = 8.53, p < 0.001$). The first interaction effect did not reveal any statistically significant pairwise comparisons ($p > 0.05$). As for the second interaction effect, we discovered that a combination of on-body image and on-body text was found to be more successful in exploring a scene compared to a combination of image + text overlay ($p < 0.001$), but it did not outperform other combinations ($p > 0.05$). Additionally, we found that on-body image and text overlay helped better in exploring a scene than image overlay combined with text in world ($p < 0.001$), but it was comparable to image + text in the world ($p > 0.05$). Furthermore, image overlay + on-body was a better assistance than image in the world + text overlay ($p < 0.001$), but it was comparable to image + text in the world ($p > 0.05$). Lastly, we discovered that a combination of image + text in the world helps better in exploring a scene than image + text overlay.

5.4 Qualitative Feedback

In general, participants reported that it was more fun to use AR glasses, it facilitated freeing both hands, while interaction with a smartphone was simple. We outline the differences with each device and the placements of images and texts in the following.

5.4.1 Interaction with Smartphone. When using a smartphone, most of the participants (N = 9) preferred image placement on the body the most, followed by overlay (N = 5) and world (N = 3). One of the remaining participants found body and world equally good and one of the them mentioned that all image placements were equally good. As for the text placement, most of the participants preferred placing text on the body (N = 11), followed by world (N = 4), and overlay (N = 4).

The reasons for the *on-body* preferences included the flexibility of reading and holding a smartphone in the most comfortable way, ease to find an information about a historical object using an info-button without losing a focus from a building in a front, which allowed alignment with a real object, and comfort of holding a smartphone down. As some of the participants mentioned: *"The information button could be used to capture the best information without shifting the focus from the building to the smartphone."* (P5), *"Body allowed for alignment with the real object and for convenient reading while looking down, relaxing the neck."* (P14), or *"With on-body it's easy to find the picture and you don't have to hold your smartphone up in the air."* (P7). On the negative side, the participants noted that it was not very intuitive and demanding to switch between a picture and a text. For example, as P6 said: *"You had to jump back and forth between image and text. I don't find it very intuitive to have a picture in an info button."*.

As for the *world* placement, participants found it more convenient to read information compared to clicking an additional info button and it was easy to have an older version of a building right next to a current one. As P17 noted: *"Having the text next to the building was the most convenient way of reading info, compared to clicking on info button."* and *"When using phone, I found it easiest to have the older version of the building next to the current one. It made it esaier to see both the versions."*. However, many participants found the *world* placement rather obstructive, distracting from focusing on a building, demanding in a sense of finding an object and moving a smartphone around. For example, some of our participants noted that: *"I found the placement in the world more of a hindrance because, unlike the glasses, it entailed an unnatural search."* (P9), *"the focus is partly on the smartphone and it is partly annoying that the image and text cover the building."* (P5), *"With the world placement you have to search sometimes until you find the picture."* (P7).

The *overlay* placement on the other hand facilitated a good connection to the physical world and a comparison between a picture and a physical building. These findings are supported by the following comments from the participants: *"Overlay is nice because I have the connection to the physical world. But (in contrast to Hololens) I can still see the physical world by just looking above the smartphone."* (P18) and *"Overlay was better since I could immediately compare the AR image to the real world."* (P15). On the other hand, participants experienced issues of *overlay* blocking the whole screen, found less convenient due to additional required movement with a smartphone and shifting focus between a smartphone and a real object. As some of our participants noted: *"Overlay was not transparent and blocked the whole screen."* (P4), *"Having an overlay required me to move the move phone in order to see the current version, adding to the inconvenience."* (P17), and *"The focus was partly on the smartphone, plus the picture and image are partly annoying since they cover the building."* (P5).

5.4.2 Interaction with AR glasses. Similarly to the usage of smartphone, with AR glasses most of participants (N = 11) preferred image placement on body the most, followed by world (N = 5) and overlay (N = 2). As for the text placement, most of the participants preferred placing text on the body (N = 13), followed by world (N = 4), and overlay (N = 1).

In particular, participants mentioned that with the *on-body* image/text placements they had a freedom to choose how and where to place an image/text according to the current lighting conditions to increase visibility and choose a position convenient to read or look at a picture, which facilitated alignment with real objects and low strain. Moreover, the on-body placement was perceived as the most fun to use, which led to lowest occlusion of environment and objects of interest. This allowed users to easily see the virtual and physical objects and hand gestures were easy and natural, similar to holding real objects in hands. As some of our participants mentioned: *"Body placement was least intuitive for me in the beginning but I liked the convenience of being able to read the info below the building on my hand, sort of an equivalence to seeing a painting in an exhibition."* (P17) and *"The texts and images that were created with hand movements (on-body placement) did not cover anything and it was super pleasant and intuitive to control."* (P5). As for the drawbacks with the on-body placement, participants mentioned that shaky hands lead to a jittery display of image/text, stretching hands out felt weird in the public place and it felt sometimes like holding a smartphone in a hand. For example, P15 noted that *"It felt weird having other people see me stretch my hands into nothingness."*, or as P18 remarked *"I end up standing like I was holding a smartphone - looking down with my hand open."*.

As for the *world* placement, participants mentioned that it reminded them of info board placed next to a historical object. For instance, P7 commented that *"With world (placement), the text looks like an information board in the landscape and is easy to read."*. On the downside, the objects placed in the world were sometimes seen as too big, which occluded much of environment and can potentially lead to dangerous situations. As P11 mentioned *"It always overlayed physical objects with virtual elements. Sometimes, this was dangerous (e.g., when not seeing a car)"*.

As for the *overlay* placement, sometimes participants could see images way better placed on the historical sites than on-body and in world, but they did not like the problem of occlusion, which led to difficulties of comparing an image to the real world and more head movements. On the positive note, participants mentioned that *"In Overlay Situation, I could see the image better than the word and body."* (P16). However, on the other hand some participants noted: *"For the overlay it was a bit difficult to compare the image to the real world since I couldn't see it properly."* (P15) and *"Overlay was often difficult to read, a lot of head movement."* (P10).

6 DISCUSSION AND FUTURE WORK

In general, we found that placing the image and text on the body resulted in greater interaction convenience for both smartphones and AR glasses. These differences in convenience were partially influenced by search movements and occlusions of the environment. While the intuitiveness of interaction with AR glasses was comparable for all combinations of placements, it was higher for smartphones with overlay images and on-body text placement. Finally, on-body placements for both images and text were most helpful in exploring the scene for both device types. We discuss these findings in detail in the following.

6.1 Convenience and Intuitiveness of Interaction

We discovered that search movements lead to poorer convenience of interaction based on the qualitative feedback. While *on-body* placements lead to the highest level of interaction convenience, *world* or *overlay* placements have shown to be comparable. One of the reasons for the high convenience of *on-body* placements lies in the lowest number of search movements, e.g., hand, head, and upper body rotations. More specifically, on the smartphone, users need to press one button to recognize the information thoroughly, and with AR glasses, they have to look at their hands to see all information (**DG1**). *World* placements, in contrast, require a single large-scale movement with the devices to the right or left to see the augmented virtual information.

Overlay placements require several small movements with the device since the virtual objects do not fit as a whole on the smartphone display and also do not lie entirely in the field of view of the AR glasses. Based on the further observations during the experiment, we can report that with the AR glasses, users' moved their heads extensively to recognize the objects fully. Compared to smartphones, participants only moved slightly since the objects were not much bigger than the screen. For images, regardless of the device, *on-body* image placements were found to be the most convenient, followed by *world* and *overlay* placements. One possible reason for the difference between *world* and *overlay* placements could be that *overlay* placements could be found easier with a single short movement compared to *world* placements, which imply longer movements or multiple small movements. This could be explained by the fact that search movements have a negative influence on the interaction convenience.

Regarding the *intuitiveness*, we found that it was comparable for both AR glasses and a smartphone. A possible reason for this could be explained by the fact that participants were informed in which direction they had to look to find the virtual objects before they got the device. If participants were still unable to find the virtual elements, they were given assistance upon request. Therefore, it might be necessary for future work to address the problem of not finding virtual elements and improve the scene exploration and discoverability of information on site. Moreover, participants were familiar with the devices, and the user interface was explained to them before the experiment, which made the interaction very intuitive.

6.2 Scene Exploration and Occlusions

In terms of Scene Exploration, *on-body* and *world* image placements perform better than *overlay*. The majority of participants mentioned that a scene could be fully explored with *on-body* placements. This can be an indicator of an occlusion problem, which participants mentioned in post-study interviews. Participants reported that the *overlay* mode shows the greatest occlusion effect since objects of interest are no longer fully visible when the virtual objects are displayed, followed by *world* and *on-body* placements. Furthermore, *overlay* image and text placements on the smartphone were rated better in scene exploration than on the AR glasses. One possible reason for this is that the view can switch between the display and the real world in the case of the smartphone, which is not the case with AR glasses. This allows a comparison between real world and historical image despite *overlay* placements (**DG2** and **DG3**). Moreover, the content itself can also affect the perceived degree of occlusion. Texts, for example, have a greater degree of occlusion than pictures independent of the placement and cannot be used for comparisons with the real world (**DG4**).

6.3 Smartphone versus AR glasses

As for the differences in interaction between AR glasses and smartphones, the *overlay* image placement on the AR glasses performed worse than *world*, in contrast to the smartphone, where the *overlay* performed better than the *world* (**DG5** and **DG6**). This difference can be explained by the more frequent small search movements on the AR glasses, where both head and hands have to be moved to find an object of interest. However, as for the text placement, both devices have shown the same results. *On-body* text placements was found to be the most convenient, followed by *world* and *overlay* text placements. Moreover, the content shown also influences convenience. It could be difficult to find a generally valid rule on how different classes of search types could influence convenience measures. Our results also indicate that more search movements might be needed to read the text completely than fully understand an image. The same applies to the AR glasses in situations with *overlay* image placements, smaller search movements were required to perceive an image than with the smartphone fully. It might also make sense that a certain number of small movements is more acceptable than a single large one. But after a certain number of movements, it could be that the participants' strategy has changed and that one big movement became more acceptable than many small ones.

It would also be desirable for practical sightseeing tours if the device were smaller, making it more comfortable to carry around, and visitors might attract less attention during use. Furthermore, future work can take a step further and explore 3D models instead of images for augmentation of sightseeing. Given that *on-body* placements have been positively perceived, we envision placing 3D models on the palm. This would enable users to rotate 3D models of a building placed on their hand and zoom in on certain parts. In this way, visitors would be able even better to compare objects from the real world and the past. Another research question relevant for future work is how much information is needed at historical sights and whether the users would like to adjust the amount of shown information themselves.

6.4 Design Guidelines (DG)

- **DG1:** To increase the convenience of use, texts and images should be placed on the body to facilitate the lowest number of search movements.
- **DG2:** Placements of texts and images should (when possible) avoid overlaying physical objects with virtual ones to decrease occlusions and facilitate comparisons between historical and real images.
- **DG3:** If overlaying is necessary, users should be able to easily toggle AR overlay visualizations to increase historical sites' visibility if demanded.
- **DG4:** AR sightseeing applications should provide additional cues to indicate off-screen objects, such as visual arrows or highlighting points of interest, to facilitate intuitiveness and ease of findings objects of interest.
- **DG5:** For AR glasses the *overlay* image placement is more convenient than the *world* placement.
- **DG6:** For smartphone the *world* placement is more convenient than the *overlay* placement.

7 LIMITATIONS

Although historical information can be presented using a variety of different media, our work focused on the visual information augmentation using Augmented Reality for images and texts. Moreover, we investigated interaction with the visual content and their placements without analyzing the knowledge transfer and efficiency of learning when visiting historical sites. During the evaluation, we also encountered several hardware and software limitations. Due to high light intensity outdoors, the virtual objects in Microsoft HoloLens 2 were not always visible. High light intensity had also influenced software limitations, such as image recognition. Given our implementation, the best object recognition could be achieved on cloudy days or in early evenings, which limited our times for running the experiment. However, with this, we aimed to reach close-to-reality experience for AR sightseeing, despite existing technological limitations. We had a limited amount and quality of historical data, but we still were able to test our approach on the limited number of historical sites in the given quality. However, it still allowed us to collect participants' impressions regarding the image/text placements and devices using available material. Moreover, our participants could only passively perceive presented information without a possibility to actively interact with a content. Nevertheless, we derived image and text placement recommendations for different devices that can help making a first step towards increasing interaction possibilities.

8 CONCLUSION

In this paper, we explored different image and text placements of information in the context of Augmented Reality (AR) sightseeing. Moreover, the evaluation included a comparison between a smartphone and AR glasses as commonly used devices to represent AR content. We found that on-body image and text placements were the most convenient compared to overlay and world for both devices. However, we did not observe differences in terms of intuitiveness for devices, all text and image placements. Additionally, we discovered that participants found themselves more successful in exploring historical sites using a smartphone than AR glasses. Finally, participants reported that exploring AR content using AR glasses was more fun with both hands being free, but interaction with a smartphone was more convenient.

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REFERENCES

[1] Kajos Attila and Bányai Edit. 2012. Beyond reality: The possibilities of augmented reality in cultural and heritage tourism. In *2nd International Tourism and Sport Management Conference, Debrecen*, Vol. 5.

[2] Betül Aydin, Jérôme Gensel, Philippe Genoud, Sylvie Calabretto, and Bruno Tellez. 2013. Extending augmented reality mobile application with structured knowledge from the LOD cloud. In *3rd International Workshop on Information Management for Mobile Applications. Citeseer*. Citeseer.

[3] Ronald T. Azuma. 1997. A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments* 6, 4 (aug 1997), 355–385. https://doi.org/10.1162/pres.1997.6.4.355

[4] C. Battini and G. Landi. 2015. 3D TRACKING BASED AUGMENTED REALITY FOR CULTURAL HERITAGE DATA MANAGEMENT. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XL-5/W4 (2015), 375–379. https://doi.org/10.5194/isprsarchives-XL-5-W4-375-2015

[5] Raffaello Brondi and Marcello Carrozzino. 2015. ARTworks: An Augmented Reality Interface as an Aid for Restoration Professionals. In *International Conference on Augmented and Virtual Reality*. Springer, 384–398. https://doi.org/10.1007/978-3-319-22888-4_28

[6] George Caridakis and John Aliprantis. 2019. A Survey of Augmented Reality Applications in Cultural Heritage. *Int. J. Comput. Methods Herit. Sci.* 3, 2 (jul 2019), 118–147. https://doi.org/10.4018/IJCMHS.2019070107

[7] Yu-Lien Chang, Huei-Tse Hou, Chao-Yang Pan, Yao-Ting Sung, and Kuo-En Chang. 2015. Apply an augmented reality in a mobile guidance to increase sense of place for heritage places. *Journal of Educational Technology & Society* 18, 2 (2015), 166–178.

[8] Francesco Chionna, Francesco Argese, Vito Palmieri, Italo Spada, and Lucio Colizzi. 2015. Integrating Building Information Modeling and Augmented Reality to Improve Investigation of Historical Buildings. *Conservation Science in Cultural Heritage* 15, 1 (Jan. 2015), 133–163. https://doi.org/10.6092/issn.1973-9494/6174

[9] Eleanor Cranmer, Timothy Jung, M Claudia tom Dieck, and Amanda Miller. 2016. Understanding the acceptance of augmented reality at an organisational level: the case of Geevor Tin Mine Museum. In *Information and communication technologies in tourism 2016*. Springer, 637–650. https://doi.org/10.1007/978-3-319-28231-2_46

[10] Areti Damala and Nenad Stojanovic. 2012. Tailoring the Adaptive Augmented Reality (A2R) museum visit: Identifying Cultural Heritage professionals' motivations and needs. In *2012 IEEE International Symposium on Mixed and Augmented Reality - Arts, Media, and Humanities (ISMAR-AMH)*. 71–80. https://doi.org/10.1109/ISMAR-AMH.2012.6483992

[11] Silvia de los Rios Perez, Maria Fernanda Cabrera-Umpierrez, Maria Teresa Arredondo, Shanshan Jiang, Jacqueline Floch, and Maria Eugenia Beltran. 2016. Technologies Lead to Adaptability and Lifelong Engagement with Culture Throughout the Cloud. In *Cultural Heritage in a Changing World*. Springer, Cham, 163–179. https://doi.org/10.1007/978-3-319-29544-2_10

[12] Joanna Dunlap, Jackie Dobrovolny, and Dave Young. 2008. Preparing e-Learning Designers Using Kolb's Model of Experiential Learning. *Innovate: Journal of Online Education* 4, 4 (February 2008). https://www.learntechlib.org/p/104215

[13] Andreas Dünser, Mark Billinghurst, James Wen, Ville Lehtinen, and Antti Nurminen. 2012. Exploring the use of handheld AR for outdoor navigation. *Computers & Graphics* 36, 8 (2012), 1084–1095. https://doi.org/10.1016/j.cag.2012.10.001 Graphics Interaction Virtual Environments and Applications 2012.

[14] Cristina Fenu and Fabio Pittarello. 2018. Svevo tour: The design and the experimentation of an augmented reality application for engaging visitors of a literary museum. *International Journal of Human-Computer Studies* 114 (2018), 20–35. https://doi.org/10.1016/j.ijhcs.2018.01.009 Advanced User Interfaces for Cultural Heritage.

[15] Hasan Shahid Ferdous, Thuong Hoang, Zaher Joukhadar, Martin N. Reinoso, Frank Vetere, David Kelly, and Louisa Remedios. 2019. "What's happening at that hip?": Evaluating an On-body Projection based Augmented Reality System for Physiotherapy Classroom. *Conference on Human Factors in Computing Systems - Proceedings* (2019), 1–12. https://doi.org/10.1145/3290605.3300464

[16] Fabian Fritz, Ana Susperregui, and Maria Teresa Linaza. 2005. Enhancing cultural tourism experiences with augmented reality technologies. The 6th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST.

[17] Alexandra Gkatsou. 2018. Enhancing the visitor experience in museums with Augmented Reality. (2018).

[18] Christina Gkiti, Eirini Varia, Chrysi Zikoudi, Athina Kirmanidou, Io Kyriakati, Spyros Vosinakis, Damianos Gavalas, Modestos Stavrakis, and Panayiotis Koutsabasis. 2018. i-Wall: A low-cost interactive wall for enhancing visitor experience and promoting industrial heritage in museums. In *Euro-Mediterranean Conference*. Springer, 90–100. https://doi.org/10.1007/978-3-030-01762-0_8

[19] Anne-Cecilie Haugstvedt and John Krogstie. 2012. Mobile augmented reality for cultural heritage: A technology acceptance study. In *2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*. 247–255. https://doi.org/10.1109/ISMAR.2012.6402563

[20] Thuong N. Hoang, Hasan S. Ferdous, Frank Vetere, and Martin Reinoso. 2018. Body as a Canvas: An exploration on the role of the body as display of digital information. In *Proceedings of the 2018 Designing Interactive Systems Conference*.

ACM, New York, NY, USA, 253–263. https://doi.org/10.1145/3196709.3196724

[21] Yi Ji, Peng Tan, and Henry Been-Lirn Duh. 2018. Research on personalized learning pattern in traditional handicraft using augmented reality: a case study of cantonese porcelain. In *International Conference on Human-Computer Interaction*. Springer, 304–316. https://doi.org/10.1007/978-3-319-91244-8_25

[22] Timothy Jung, Namho Chung, and M. Claudia Leue. 2015. The determinants of recommendations to use augmented reality technologies: The case of a Korean theme park. *Tourism Management* 49 (2015), 75–86. https://doi.org/10.1016/j.tourman.2015.02.013

[23] Jens Keil, Laia Pujol, Maria Roussou, Timo Engelke, Michael Schmitt, Ulrich Bockholt, and Stamatia Eleftheratou. 2013. A digital look at physical museum exhibits: Designing personalized stories with handheld Augmented Reality in museums. In *2013 Digital Heritage International Congress (DigitalHeritage)*, Vol. 2. 685–688. https://doi.org/10.1109/DigitalHeritage.2013.6744836

[24] Jens Keil, Michael Zoellner, Timo Engelke, Folker Wientapper, and Michael Schmitt. 2013. Controlling and filtering information density with spatial interaction techniques via handheld augmented reality. In *International Conference on Virtual, Augmented and Mixed Reality*. Springer, 49–57. https://doi.org/10.1007/978-3-642-39405-8_6

[25] Chairi Kiourt, Anestis Koutsoudis, and George Pavlidis. 2016. DynaMus: A fully dynamic 3D virtual museum framework. *Journal of Cultural Heritage* 22 (2016), 984–991. https://doi.org/10.1016/j.culher.2016.06.007

[26] Chris D. Kounavis, Anna E. Kasimati, and Efpraxia D. Zamani. 2012. Enhancing the Tourism Experience through Mobile Augmented Reality: Challenges and Prospects. *International Journal of Engineering Business Management* 4 (2012), 10. https://doi.org/10.5772/51644

[27] Panos Kourouthanassis, Costas Boletsis, Cleopatra Bardaki, and Dimitra Chasanidou. 2015. Tourists responses to mobile augmented reality travel guides: The role of emotions on adoption behavior. *Pervasive and Mobile Computing* 18 (2015), 71–87. https://doi.org/10.1016/j.pmcj.2014.08.009

[28] Panos E Kourouthanassis, Costas Boletsis, and George Lekakos. 2015. Demystifying the design of mobile augmented reality applications. *Multimedia Tools and Applications* 74, 3 (2015), 1045–1066. https://doi.org/10.1007/s11042-013-1710-7

[29] Laia Pujol, Maria Roussou, Stavrina Poulou, Olivier Balet, Maria Vayanou, and Yannis Ioannidis. 2012. Personalizing interactive digital storytelling in archaeological museums: the CHESS project. In *40th annual conference of computer applications and quantitative methods in archaeology. Amsterdam University Press*. 93–100.

[30] R Quattrini, R Pierdicca, E Frontoni, and R Barcaglioni. 2016. VIRTUAL RECONSTRUCTION OF LOST ARCHITECTURES: FROM THE TLS SURVEY TO AR VISUALIZATION. *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences* 41 (2016).

[31] Alexandra Rese, Daniel Baier, Andreas Geyer-Schulz, and Stefanie Schreiber. 2017. How augmented reality apps are accepted by consumers: A comparative analysis using scales and opinions. *Technological Forecasting and Social Change* 124 (2017), 306–319. https://doi.org/10.1016/j.techfore.2016.10.010

[32] Ulrike Spierling, Peter Winzer, and Erik Massarczyk. 2017. Experiencing the presence of historical stories with location-based augmented reality. In *International Conference on Interactive Digital Storytelling*. Springer, 49–62. https://doi.org/10.1007/978-3-319-71027-3_5

[33] TamásMatuszka and Attila Kiss. 2014. Alive Cemeteries with Augmented Reality and Semantic Web Technologies. *International Journal of Industrial and Manufacturing Engineering* 8, 2 (2014), 302 – 306. https://publications.waset.org/vol/86

[34] David R. Thomas. 2006. A General Inductive Approach for Analyzing Qualitative Evaluation Data. *American Journal of Evaluation* 27, 2 (2006), 237–246. https://doi.org/10.1177/1098214005283748

[35] M. Claudia tom Dieck and Timothy Jung. 2018. A theoretical model of mobile augmented reality acceptance in urban heritage tourism. *Current Issues in Tourism* 21, 2 (2018), 154–174. https://doi.org/10.1080/13683500.2015.1070801

[36] David Vanoni, Samantha Stout, Antonino Cosentino, and Falko Kuester. 2015. ARtifact conservation: representation and analysis of spectroscopic and multispectral imaging data using augmented reality. In *Scientific Symposium at the General Assembly of the International Council on Monuments and Sites (ICOMOS)*.

[37] Gheorghe-Daniel Voinea, Florin Girbacia, Cristian Cezar Postelnicu, and Anabela Marto. 2018. Exploring cultural heritage using augmented reality through Google's Project Tango and ARCore. In *International conference on VR Technologies in Cultural Heritage*. Springer, 93–106. https://doi.org/10.1007/978-3-030-05819-7_8

[38] Jacob O. Wobbrock, Leah Findlater, Darren Gergle, and James J. Higgins. 2011. The Aligned Rank Transform for Nonparametric Factorial Analyses Using Only Anova Procedures. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Vancouver, BC, Canada) *(CHI '11)*. Association for Computing Machinery, New York, NY, USA, 143–146. https://doi.org/10.1145/1978942.1978963

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