“I was Holding a Magic Box”: Investigating the Effects of Private and Projected Displays in Outdoor Heritage Walks

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Figure 1: Example of a handheld projector user projecting on a site (left) and a smartphone user looking at their screen (right).

ABSTRACT

Location-aware mobile guides are a popular technology for enhancing the experience of heritage walks in historical outdoor sites. Smartphones, as typical mediums for such systems, have been criticised for limiting users’ opportunities for embodied engagement with the environment. In this work, we investigate how display technologies beyond the traditional personal mobile screen can facilitate embodied experiences during outdoor heritage walks. To do this, we revisit the use of portable projected displays as a medium that allows us to explore the effects of overt and blended displays in this context. We conducted a study with 42 participants on an outdoor heritage walk, using two display modalities: smartphone and projected display. We discovered that besides the display modality, users’ attitude toward technology, their embodied relationship with the device, and incorporation of spatial aspects in interaction play a key role in generating engagement and shaping the experience of heritage walks.

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CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**; *Interaction devices*; • **Information systems** → Location based services.

KEYWORDS

Handheld Projectors; Location-aware mobile guides; Cultural Heritage; Heritage walk; Embodied Experience; Field Study

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1 INTRODUCTION

Millions of people visit outdoor heritage sites every year for leisure, learning, or simply to engage with new cultures. Visiting a place in person gives people an opportunity to engage with the physical and social environment of the site and form rich experiences and memories. Mobile technologies are now commonly employed to enhance the experiences of visitors at outdoor heritage sites.

Handheld location-aware mobile guides (hereafter called *mobile guides*) are widely used to assist walking-driven exploration and enhance visitor experiences [17, 64]. Within that context, recent

work in the area of heritage studies, technology and human computer interaction (HCI) has placed significant emphasis on the value of designing systems to support embodied experience, and facilitate the formation of valuable personal interpretations [10, 13, 55]. Research suggests that in order to deliver rich and meaningful experiences, systems for heritage walks need to afford: 1) holistic awareness of surroundings; 2) corporeal engagement with the physical heritage site; and 3) social interaction and co-construction of meaning [10, 34, 48].

In the context of cultural heritage walks, smartphones have now become the typical platform to deploy location-aware guides to enhance users' experiences. Although smartphones can provide exciting opportunities for interaction and participation in cultural heritage walks [25, 53], their design emphasises a predominantly heads-down interaction, which limits the users' engagement with the physical environment. By drawing the visitors' attention away from the physical space onto a framed window, these technologies lower spatial awareness, the engagement with the heritage site and increase social isolation [28, 52].

In this work, we focus primarily on the effects that alternative display technologies can have on the experience of participants, with respect to their engagement with the physical and social environment. Prior work includes several attempts at revealing content directly in the physical space of the heritage sites through different types of digital augmentation and interaction techniques to overcome the head-down interaction [31, 58, 59]. Motivated by such attempts we further consider the effects of display technologies that allow shared views of content, as well as content blended with the physical environment, and their potential in enabling holistic awareness of surrounding, corporeal engagement with the heritage site, and social interaction.

There is a range of potential technologies that can satisfy the characteristics of shared and blended information. Augmented Reality (AR) glasses and head-mounted displays can offer ways to blend information with the physical world, while public displays can allow shared views of information. In this work, we consider the use of portable projected displays as a device that allows us to study the effects of both characteristics within the context of heritage walks.

Although there is work on how handheld projectors can enhance shared social encounters [3, 36], enable situated learning [60] and support affective experiences [33] in a range of contexts (schools, museums, etc.), there has been limited focus on studying how such display technologies affect the experiences of users in outdoor heritage walks. The outdoor nature of heritage walks, the blending with people who are not visitors of the site, and the varied characteristics of the environment reveal a unique setting that opens up new questions about how such technologies can influence users' behaviour and interaction.

In our study, we address this gap and set out to explore the possibilities afforded by projector-based guides to mediate embodied experiences and meaning-making in the context of outdoor heritage walks by contrasting them against smartphone-based guides. Our ultimate objective is to provide a preliminary understanding of the potential of these technologies in outdoor heritage walks, thus informing theoretical and design research. Specifically, we investigate:

(1) How do different display technologies affect users' awareness of the environment during outdoor heritage walks?
(2) How do different display technologies shape users' engagement with the environment and other people during outdoor heritage walks?
(3) How does the attitude of users towards the employed display technologies influence their experience in outdoor heritage walks?

To answer these questions, we conducted a study involving 42 participants, using two display technologies (smartphones and portable projectors) during an outdoor heritage walk in Canterbury, a mediaeval city in the UK. Through a combination of video observations, interviews, and drawings, we were able to understand the interplay between the characteristics of each display technology and the users' experience.

Our findings show that screen and projected displays scaffold different ways of inhabiting, engaging with, and being aware of the physical space during outdoor heritage walks. During the heritage walk, *projector guide* users walked slower and reported having agency, control, and opportunities to play. They also exhibited better spatial, social, and somatic awareness. *Phone guide* users, on the other hand, reported feeling socially isolated and disconnected from the site. This indicates that handheld, public, and blended displays have the potential to support embodied meaning-making and aesthetic experience. Based on our findings, we discuss a series of design directions for mobile guides to enhance the experience of outdoor heritage walks.

2 BACKGROUND

2.1 Slow walking for 'rich' heritage experiences

Typically, museums display historic artefacts (removed from their original context) in sterile environments, for 'seeing' and 'do not touch'. In contrast, outdoor heritage sites, consist of buildings and spaces that were constructed during the time period that they represent, creating spaces where visitors can 'insert' themselves [48] to make sense of the communal past and cultural heritage. At such sites, cultural and historical narratives are intertwined with not only the points of interest (POIs) but with the material and social setting, as well as the atmosphere of the whole 'sensory space' [48]. Hence, they are best experienced with all senses actively engaged.

This approach moves us away from the traditional paradigm that treats heritage as something that can be objectified. Instead, it inspires new curatorial approaches that enable visitors to form personal interpretations and memorable experiences. As argued by Naumova [48], such impactful and complex interpretations can emerge from the corporeal and tactile engagement (movement, gestures, etc.) within these settings. Lasting impressions can transpire from aesthetic experiences [2], which have been defined as being immersed or "indulged in environments" [51]. Such experiences emerge from 'being-there' and are associated with the intertwining of perception, attention, action, memory, imagination, thought, and emotion [42].

In outdoor heritage walks, the act of walking constitutes the basis for embodied and aesthetic experiences. This is because walking is not just the act of moving through the site, but also becomes a way

to (i) engage people's multisensory, affective, and physical capacities while they touch the ground with their feet, see, hear, and smell the surroundings, [12, 27]; (ii) learn about the space by connecting and engaging (emotionally and physically) with the material and social aspects of the space; (iii) enact their agency by responding to it [48, 56]. Consequently, a slower paced walk: (i) allows people to be completely aware of their actions and the external environment through all their senses (instead of the dominant use of visual perception); (ii) enables people to consciously exercise their movement and actions; and (iii) creates opportunities for walkers to participate and interact with events and passers-by [15]. As a result, slow and responsive walking becomes an essential methodology for enabling visitors to have richer experiences at the heritage site [48, 68]. It is therefore important to compare how different technologies used in cultural heritage afford slower paced walking and how this is appropriated by users.

2.2 Mobile technologies in heritage walks

In recent years, opportunities for blending the digital and physical worlds have emerged, with a focus on AR or Mixed Reality (MR) applications. These applications are usually designed to provide augmented information in different ways: (i) via a screen (i.e., smartphones, tablets); (ii) via near-to-eye projection (AR glasses); or (iii) via projection onto the physical world (i.e., projectors).

To support navigation and access to certain site-specific content, location-aware smartphone-based technologies have been intensively used in the context of learning, cultural heritage, and tourism [4, 25, 53]. Despite these advantages, smartphones also have limitations resulting from the narrow field of view and the way users end-up looking down at the screen while interacting with information [58]. This usually leads to divided attention, cognitive distraction, and reduced situational and spatial awareness (which can be dangerous for pedestrians) [38, 47]. While smartphones are useful for various other purposes, these limitations arguably make smartphone-based systems unfit for supporting visitors' exploration, chance discovery of interesting elements (e.g., physical, historical) and enjoyment of the surroundings during the heritage walk [49]. To overcome these limitations of smartphone researchers have explored embedding visual markers in the site to trigger narration [49] during a heritage walk. Alternatively, researchers have explored multi-modal interaction techniques to direct the users' attention towards their surroundings. Examples of proposed solutions involve audio guides [1], audio-augmentation [66] and vibrotactile feedback [23, 24] to assist users in finding POIs along the heritage walk. Although most of these systems allow users to navigate to a POI without visual distraction, once they reach their destination, the information is either delivered on the screen, which continues to function as a "digital divider" or the system lacks visual information.

AR glasses (e.g., Microsoft Hololens) can remove this "division" and seamlessly blend the digital content and the physical surroundings, thereby affording enriched interaction with the augmented world. Yet currently available smart-glasses present limitations in terms of price, battery life, display quality (resolution and contrast) and user-friendly interactions [20, 39, 65]. Furthermore, AR glasses are inherently a form of personal display, a feature that can lead to an isolated experience and discourage opportunities for the user to engage with other people, thus limiting the social aspect of heritage walks.

Handheld projectors are a readily available technology that combine projective AR configurations with possibilities for embodied interaction by augmenting the physical surroundings with digital information – in the form of a blended display – without the need for onsite installations. As a result of framing the physical-digital relationship differently, projectors afford a different hierarchical structure to the experience [41]. Furthermore, projected displays are inherently public displays, allowing for a shared view of content by multiple people. These characteristics have the potential to facilitate the engagement of the user with their surroundings as well as support social interaction and the co-construction of meaning – functions that have the potential to deliver rich and meaningful experiences in heritage walks [10, 34].

From a technological standpoint, handheld projectors are not novel and present a series of limitations (e.g., low visibility in bright light; interference from texture and colour of the surface projected upon; potential instability due to the user's hands shaking). Nonetheless, as Malinverni et al. [41] point out in their study, the use of this technology is still in its infancy and there is a need to analyse its potential in a variety of scenarios. Furthermore, as a study instrument, projected displays allow us to study the specific effects that blended and shared displays can have on the experience of users in the context of a heritage walk.

Most of the research on handheld projectors has focused on exploring different interaction techniques, exploring their technical application, and testing their usability [8, 67]. Furthermore, most of these studies report on the usability effect of using projected displays in indoor lab settings. Within the field of cultural heritage, past studies have focused on supporting information sharing within a group [3, 19, 36], situated learning [60] and affective experience [34]. Yet, these studies have not explored the opportunities afforded by the features of handheld projectors for supporting embodied engagement and their effects on walking patterns during outdoor heritage walks.

Smartphone-based and projector-based systems are different media with their own specificities. It is therefore important to understand their role in mediating user experience, meaning-making, and their underlying affordances.

3 METHODOLOGY

Our experimental design was aimed at discovering insights related to how mobile guides based on different technologies facilitate and shape the experience of participants during outdoor heritage visits, with respect to their engagement with the physical and social environment. For this purpose, we conducted a comparative field study where two groups of participants were invited to an outdoor heritage walk (see Fig. 2), where they used a portable guide application (see Fig. 3): *phone guide group* used a smartphone, *projector guide group* used a portable projector display. The walk took place along the high street of a mediaeval city of historical significance. To maintain consistency in experimental conditions during data collection, participants used the same application within the same outdoor public space.

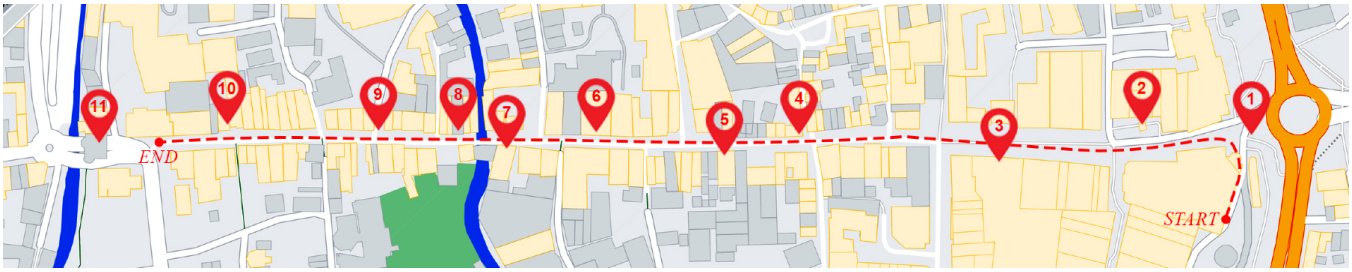
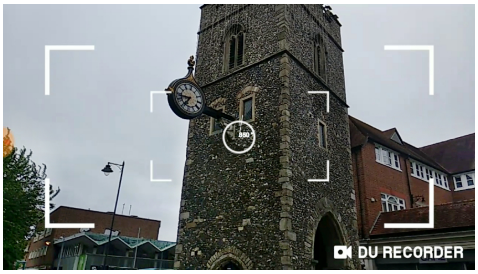
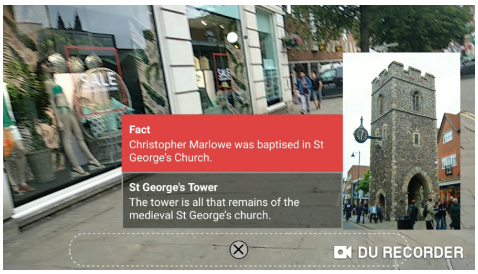


Figure 2: Map of the Heritage Walk indicating the route and locations of the selected points of interest.



(a) View of the user interface while walking.



(b) View of the user interface with content.

Figure 3: Graphical interface of the Android application.

3.1 Walk route and POIs

Given that one of the motivations of our study is to understand how different displays shape users' engagement with other people, we chose the High Street as a setting for our experiment. This outdoor multi-use public space allowed us to observe the socio-cultural effects on users and the reactions of passers-by. The High Street provided a relevant and authentic context for a heritage walk as it contains many POIs in the form of heritage buildings and is a popular tourist destination. The location is pedestrianised, with very limited vehicular access, which could ensure the safety of participants during the study. Lastly, as a straight and approximately 800-meter long street, it was a reasonable length for the walk in terms of distance and duration (see Fig. 2).

Eleven heritage buildings were shortlisted as the POIs for the walk. We selected them for their historical and cultural value, and to ensure an optimal number and even distribution for the length and duration of the route. The POIs represented different time periods and were in different physical conditions. Some buildings had completely disappeared (non-existent), some were partly visible or had been adapted for a different use, and some were still in use as originally intended.

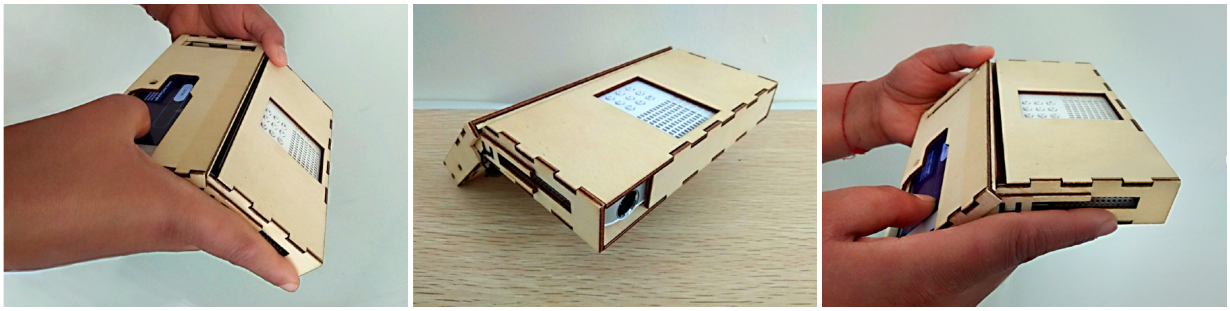
3.2 Application design

A simple location-based Android application was developed for the study, designed to track users' locations and notify them when within ca. a $9m$ radius of one of the POIs. Notifications were provided via audio and vibration feedback, so users were not required to constantly look at the screen. The app did not provide navigation guidance. At the start of the walk, participants were verbally briefed about the route which was fairly straight and culminated at a clearly visible landmark.

Notifications were followed by the display of content in the form of textual information about the site and images (see Fig. 3b) on the screen. The *projector guide* users projected the same content in the same layout during the walk. To eliminate the effects of storytelling on users' engagement [34], we did not interconnect the information about different buildings in a narrative. The information we chose consisted of facts, images (current state), and where possible, a historical image or artistic visualisation. Information was presented in one or two slides which participants could swipe between on the smartphone screen. Images were included to help participants identify POIs.

While walking, the interface provided a camera view overlaid with a viewfinder graphic for *phone guide* users (see Fig. 3a). Alternatively, the interface for the projected display showed a viewfinder graphic on a black background, which acted as a transparent background when in use. To maintain consistency across both modalities, we kept the layout of the application in landscape orientation.

For the *projector guide*, a smartphone was wirelessly connected to a portable projector (LightBeam 200C) using the casting feature. As shown in Fig. 4, both devices were placed in a custom-made case, so that users could perceive and use them as a single integrated device. Since participants were going to use the device outdoors, we assumed they would prefer to project either on walls or on the floor while walking. Therefore, we estimated an optimal angle between screen and projection [8] (45° inclination in relation to the screen), so that users could maintain a natural wrist position. The smartphone screen was partially covered, but still allowed users to interact with the application.



(a) Grip to direct projection on floor. (b) Case for smartphone & projector. (c) Grip to direct projection on wall.

Figure 4: A custom-made case for *projector guide* housing a smartphone and portable projector.

3.3 Participants

In total, 42 participants took part in the study (P1–P21: projector guide users; M1–M21: mobile guide users; 21 females and 21 males; ages 18–35), recruited via a call for participation shared through university mailing-lists. All participants were students who lived in the city for a period ranging from 1 week to 8 years. All participants had visited the High Street before our experiment for various purposes, such as shopping or socialising, but only one participant had visited it for an outdoor heritage walk (touristic purposes). Participants were randomly assigned to one of the two modalities, with 21 participants (M1-M21) using the app on the smartphone (*phone guide*), and 21 participants (P1-P21) using it with the projected display (*projector guide*). To ensure a balanced representation, we allocated participants so that the levels of familiarity with the site remained broadly similar across the two groups.

3.4 Data collection

Before beginning, participants were briefed about the data collection process, activity, route, app features, and safety guidelines. They were also given a participant information sheet and signed a consent form, approved by the ethics committee of our institution. Participants were then given the modality they were assigned. For consistency, the app was installed on a single device, and all participants used the same smartphone. Furthermore, to facilitate a more 'natural' scenario, participants were not given instructions about using the device, a time limit, or any guidelines other than to look out for their safety. The number and names of POIs included in the walk were not shared beforehand with participants as we wanted to observe how they chose to explore the site. Researchers did not intervene other than to respond to participants' queries about the walk or other concerns (e.g., rain). Walks lasted approx. 20 minutes and took place in the early evening to account for the projector's display limitations during the daytime. During the walk, a researcher followed the participants and captured **video-recordings** with a handheld video camera. Afterwards, participants were invited to a nearby cafe for a semi-structured **post-activity interview**, conducted to gain further insights into their experiences. Interviews lasted approximately 30 minutes and were audio recorded. Additionally, a **drawing activity** was introduced during the interview, where participants were given paper and pens, and were asked to draw a significant or memorable moment from the walk and to include themselves in the drawing. This was done to gain qualitative understanding of users' attention and somatic awareness [21, 32, 50], their experiences [16] and their perception of geographical layouts [62]. Upon completion of the session, participants received a gift voucher.

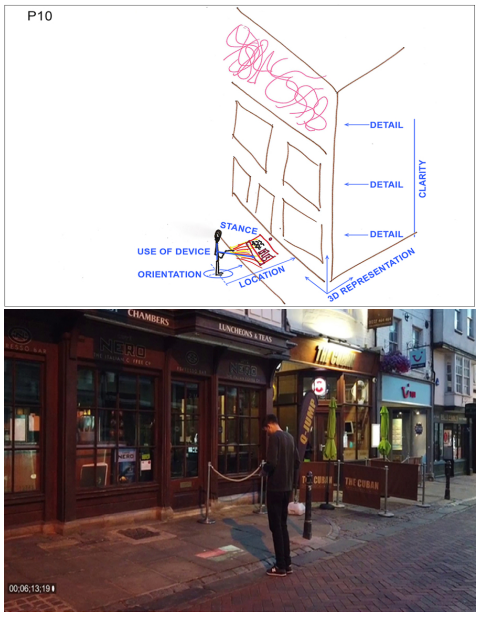
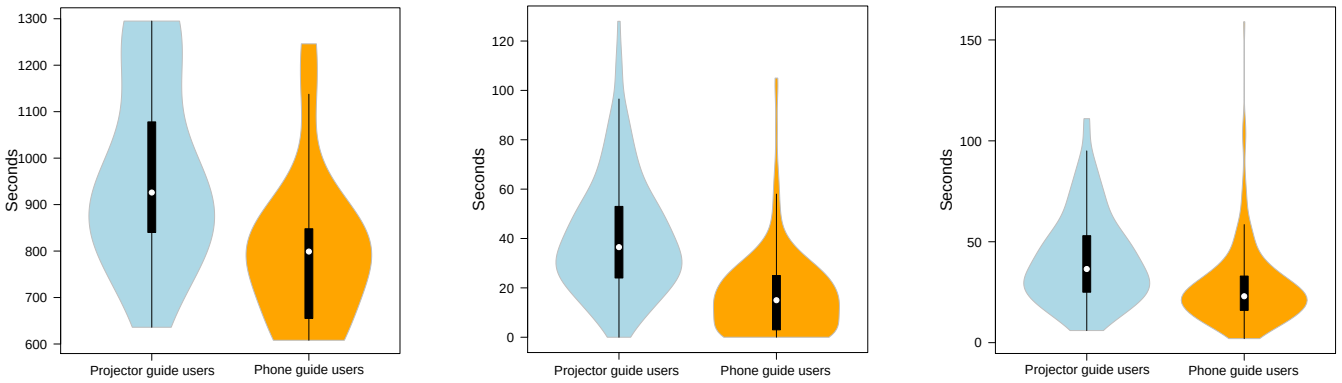


Figure 5: An example of how drawings were coded and how the codes were verified against video recordings.

3.5 Data analysis

The video recordings, drawings and semi-structured interviews were analysed following a multimodal approach [30] to study the effects of the two display modalities on users' body awareness [22], awareness of surroundings [37], engagement and experience during the outdoor heritage walk.

All **video recordings** were coded to analyse: a) participants' behaviour while walking between heritage buildings (path, gaze, use of device); b) participants' behaviour at each heritage building (orientation, movement, gesture [63], use of device); and c) halt



(a) Comparison of overall walk duration

(b) Comparison of halt duration at heritage buildings

(c) Comparison of read & view duration at heritage buildings

Figure 6: Walk duration violin plots for phone guide and projector guide users.

duration (time spent in each location) [35] and total walk duration [5, 61]. The preliminary coding and observatory notes for each walk were prepared by the lead researcher. These were then discussed with two other researchers while viewing selected portions of the video. During the discussion, corresponding interview data was also referred to, in order to verify and improve the validity of observations. Based on these codes and notes, we conducted a qualitative analysis of the relationships between the user, their physical and social environment, and the device. Certain moments from different walks were chosen as examples, which were then decomposed into image sequences and transcribed for aspects related to body movement, orientation, proximity, gestures, and the use of devices in relation to the physical environment.

The outcomes of the **drawing activity** were analysed for two key aspects: a) participants' awareness of their body and physical surroundings; and b) participants' view on which elements played a key role in shaping their experiences. To study participants' proprioceptive and egocentric location (body-space relation) awareness, we observed the representations of body stance within the drawing (posture-gesture), orientation, and location with respect to their surroundings. To evaluate participants' visual and spatial awareness of their surroundings (see Fig. 5), we annotated the drawings in terms of representation of space (3D or 2D), representation of scale (loose/fair/good), and level of clarity and detail (limited/fair/good) [37]. We also analysed representations of the device and the quality and detail of the other elements represented in the drawing, as well as verified participants' representations of themselves against video records of the same moment for further reliability. Initially the drawings were coded by the lead researcher. The assigned codes were then reviewed by a second researcher. After the review, heuristics used to code the drawings were discussed between the team for further clarity and consistency. Based on the revised heuristics, codes on few drawings were modified to arrive at the consensus.

Lastly, audio-recordings of **post-activity interviews** were transcribed, coded, and labelled by the lead researcher using thematic analysis [6]. Initial codes were assigned (i.e., 'awareness', 'embodied engagement', 'experience of using the device', and 'experience of heritage walk') based on the research questions. Subsequently, more codes were added to capture significant thoughts reported by participants. The coding was reviewed by a second researcher who did not participate in the data collection. Following the review and discussion, codes were refined, re-articulated and reassigned as required to arrive at consensus.

Based on the combination of data (i.e., videos, drawings, and post-activity interviews), the results were verified and categorised into the following themes: 1) *Walking patterns and behaviour*; 2) *Awareness and feelings of 'being there'*; 3) *Embodied engagement and meaning-making*; and 4) *Social engagement and experience.*

4 RESULTS

Participants from both user groups acknowledged that doing the walk using a mobile guide was an informative experience. However, the results indicate that their embodied and social experiences were influenced differently, depending on which of the two display technologies was employed.

4.1 Walking patterns and behaviour

On average, *projector guide* users took more time to complete the walk and while stopping at each building, as well as reading and viewing the provided information compared to *phone guide* users (see Fig. 6). The fact that they were **walking slowly** was noted by participants in the interviews: *"I was walking fairly naturally, perhaps a little slower"* (P9), and *"it might have slowed me down a little [...] in a good way"* (P18). One of the reasons *projector guide* users spent more time during the walk might be because of the need to stop and find a good surface to project on: *"I have to search for a relatively dark area so that I can see the projection [...] Sometimes, it's like you have to change the position several times"* (P6). However, in the process of trying to find appropriate surfaces to project on, participants had more opportunities to interact with the POI.

Similarly, this extrovert and blended nature of the projected display led to a more **exploratory walking** pattern, during which users spent more time absorbing and observing their surroundings [15]. Having the display projected in the surrounding motivated people to use it to interact with the street from different vantage

Figure 7: An example of a projected display user exploring and walking a zigzag path on the street (P1).

points. Fig. 7 illustrates P11 **walking in a zigzag path** along the street to approach elements that evoked their interest. Their overall body movement reveals attempts to explore the environment - e.g., changing orientation (frames 6, 10, 15), positioning themselves in close proximity, and performing probing gestures (frames 7, 12). Another *projector guide* user noted they were *"going this zigzag motion or at least sticking towards the middle"* (P5) because that provided a better experience.

On the other hand, we observed that *phone guide* users tended to walk as commuters rather than as explorers. They often walked with the intent of getting to the next building and without paying much attention to other events or things happening around them: *"I personally walk quite fast, and I think that influenced the fact that I didn't stop. I just kept going"* (M2). Moreover, the video observations revealed that they often began walking away from the heritage building before they had completely read the information on screen. Significantly, 38% of *phone guide* users did not halt at more than half of the heritage buildings after the notification. Their engagement was limited to a glance or two at the historic buildings.

During the interviews, M2 elaborated: *"I'm always on my phone when I am in town. So I have sort of like an awareness of the surroundings, [...] as I walk, I don't have to look up"* (M2). This familiarity with walking with a smartphone could be one of the reasons that led users to walk in navigation-based mode, as they perceived the walk as identical to a normal walk with their phone. While using the phone, participants acted out of habit: *"I definitely found myself looking at the screen. Even at times when it wasn't prompting me. Just out of habit"* (M4). Furthermore, these 'habits' of using the phone led to some users expressing dissatisfaction when their customs were interrupted. For example, M15, M20, and M21 prefer to have their phones in their pockets while walking. Therefore, they felt weird about holding the phone for the entire duration of the walk *"I would not prefer to hold the phone in my hand and walk. I would usually prefer it being in my pocket"* (M15). Additionally,

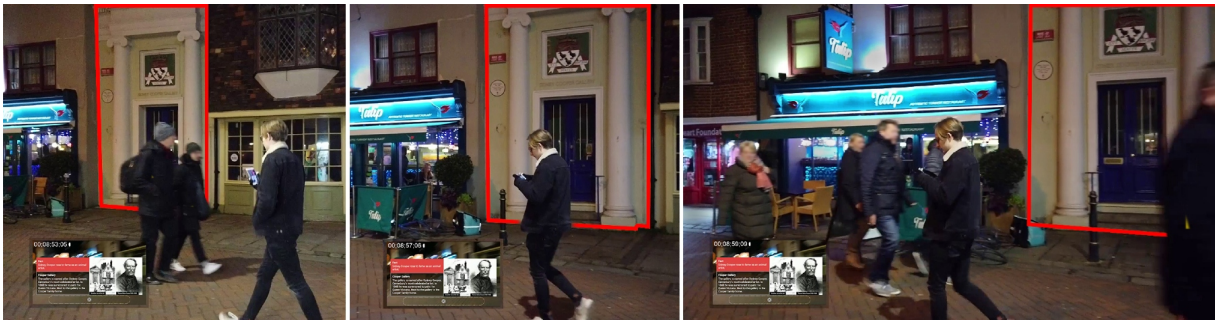
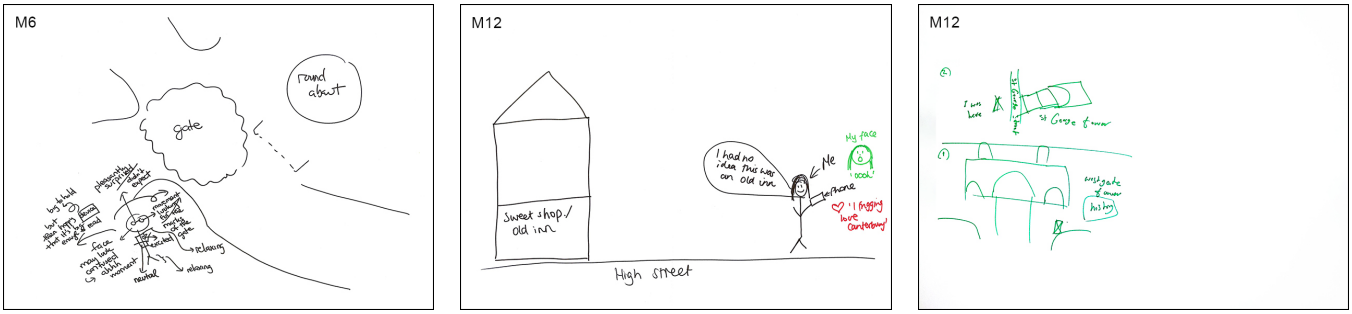


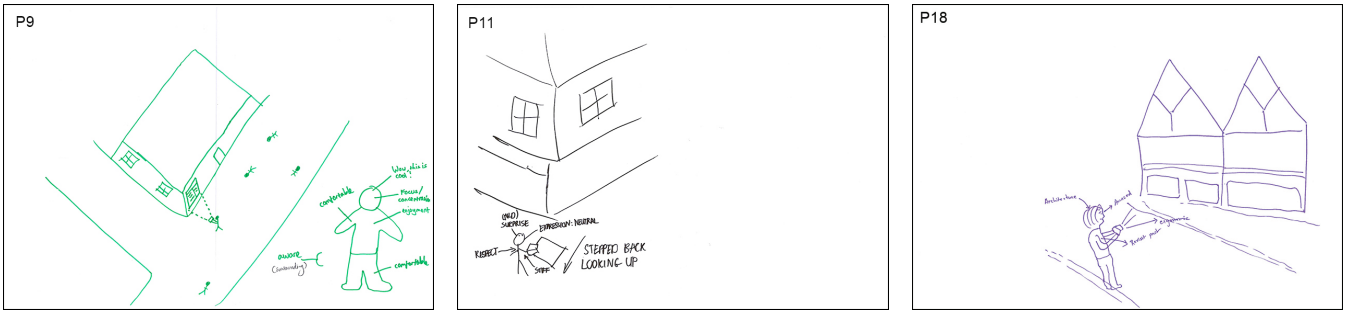
Figure 8: An example of a phone guide user (M21) who missed the building (highlighted in red) and continued walking.



(a) M6 represented space as a 2D plan.

(b) M12 marked their location in space.

(c) M14 drew themselves, device, & building but lacked attention to relative disposition.



(d) P9 drew passers-by whose attention they wanted to grab by projecting on the wall.

(e) P11 drew how they re-positioned themselves to get a better view of the building.

(f) P18 represented themselves projecting onto the heritage building façade.

Figure 9: Drawings created by *phone guide* users (a, b, c) and *projector guide* users (d, e, f) after the outdoor heritage walk.

M2 expressed their uneasiness about having to hold the phone in landscape instead of portrait orientation during the walk: *"I was holding in landscape and obviously that is not a natural way to hold it. It felt a bit unnatural"* (M2).

4.2 Awareness and feelings of "being there"

Throughout the study, participants expressed that using the mobile guide motivated them to pay **attention to the architecture and buildings**. *Phone guide* users made explicit comments about focusing their attention on the various buildings during the walk but feeling disconnected from the rest of their physical and social surroundings. M9 commented *"[the phone guide] connected me with the stops, [...] but it disconnected me from those shops, restaurants"* (M9), and M16 noted that *"it was maybe one of the first times I walked and, I wasn't looking at the people, I was looking at [...] the buildings and the surroundings"* (M16). However, another participant mentioned that the display of information compromised their awareness of their surroundings: *"[it] distracted because whenever the history or something pop[s] up [...] I totally focused on reading [...] I don't know whoever is passing me and what building I pass through"* (M20). This was also evident in the case of M21 (see Fig. 8), who missed one of the POIs completely and continued walking while reading information on the screen.

Projector guide users also reported that the information notifications demanded their attention: *"when there was [...] a pop-up, it did [...] momentarily [...] grabbed all of my attention"* (P18). Despite this,

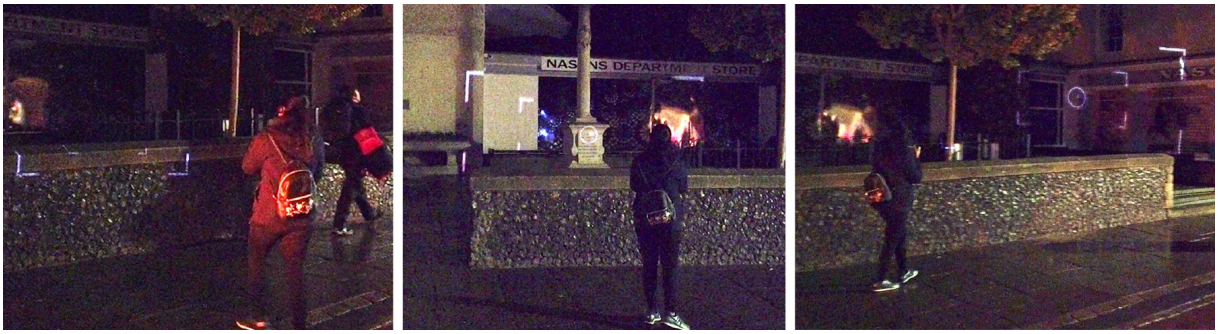


Figure 10: An example of *projector guide* user enacting exploration by scanning the physical environment (P18).

their description of how they experienced the interference with the surroundings was different: *"I was looking at the projection a lot of the time [but] I still felt like I knew more about what was happening around me, because it was like peripheral vision"* (P21). In addition, they often mentioned that besides observing the different buildings, they also remained **aware of other people** during their walk *"I was more conscious of everyone else around me because [...] I was pointing it [projector] out to people's way"* (P5).

Overall, *projector guide* users were **more aware of their environment**. This is also evident from the drawing analysis (see Fig. 9), where the awareness of the geometric qualities of space, and attention to scale and detail was better amongst projected display users. There were significant differences between the two groups P and M, particularly on: (1) the depiction of the environment as a 3D space (P: 66% vs. M: 38%); (2) good accuracy of scale (P: 48% vs. M: 10%); and (3) good clarity in representation (P: 71% vs. M: 42%). Specifically, we found that in the drawings, *projector guide* users depicted corporeal aspects of their experience, such as stance (kinesthesis; proprioception), orientation, and position in space (egocentric location) more accurately than *phone guide* users. To confirm this, we verified the drawings against the video. Our results indicate that projected display users were **more aware of their actions** in relation to the physical world. It has been suggested that such conscious awareness towards one's own actions contributes towards stronger feelings of presence and 'being-there' [69].

4.3 Embodied engagement and meaning-making

Throughout the study, we observed that both *phone guide* users and *projector guide* users engaged in **embodied meaning-making with the heritage site** (the High Street) and the eleven heritage buildings. However, this embodied meaning-making was realised differently across the two user groups, shaping their experiences differently. To better understand this, during the video analysis we focused on users' body movements and gestures.

Scanning and **pointing** were two common gestures observed among *projector guide* users, which enabled them to **interact with the physical environment**. Fig. 10 shows a participant (P18) pointing the projector towards the walls, moving it across in a *to-and-from* motion to scan the surroundings and check if the encountered buildings featured in the heritage walk or not. This was reinforced by another participant during the interview: *"I was just scanning everywhere [...] especially when [...] that building or [...] place had [...] some kind of history"* (P3). P10 further explained that such gestures enabled them to **have agency** as well as **form connections with the building** *"you could position it [projection] where you wanted [...] you can see it and then from that [...] join it with the site"* (P10). P5 referred to the experience of holding the box as *"I was holding [...] a magic box"* (P5) and explained that *"the fact that you're in control of where the plaque is, and sort of where the [projected] information is. There's something about it, that [...] gives you control over how the information is presented to you"* (P5) and another discussed that they could momentarily alter their surroundings *"it's literally another way to look at the world, because you are projecting something that you have, [...] you can control something that's there, that you can't change. But you can change it for a second when you put that thing [projected information] on top of the real thing"* (P19). Such an ability to momentarily alter one's surroundings has also been suggested to contribute to the sense of 'being-there' [69].

Projector guide users engaged in actions that can be interpreted as an attempt to 'link', **to connect the digital and physical** and to engage in play. For example, after P19 received a notification, they projected information onto the nearest building. When they realised the information was not linked to the right POI, P19 changed their position to face the correct building. They then crossed the street - to increase the distance to the building - and projected from their location, creating a larger image (see Fig. 11). They explained during the interview: *"Being able to compare on real, on a scale, [...] you can put it [projected display] on top of a real-life building [...] which is much more fun"* (P19).

Additionally, users suggested that using the projected display gave them an **ability to augment the physical reality** *"I guess you could say it is basically augmenting real life. it's taking real life and enriching it with more information"* (P9). Within the heritage context *projector guides* allowed the participants to *"merge old with new because all these buildings have a lot of history and this is like new technology and you can like know something good"* (P2). Moreover, users of projector displays found in their experience a chance to *"do a comparison. Does it look similar? What is the difference between the times this picture has been taken and the picture now?"* (P6).

In general, this ability to project onto the surroundings was well received by participants who described their experience as **interactive, playful and fun**: *"I like the interactive aspect of it [...] it feels like it's got more purpose to it"* (P12). Reported experiences

Figure 11: P19 relocates to project onto the correct building and compare old image with the current building.

of play were also related to observing the distorted image *"it's funny to just project something on the wall and look how the shape changes"* (P2), or observing the changes the projections caused in the surroundings: *"to play with lights and confusing the people was fun [...] playing with the surfaces [...], [how buildings] change when you put the projector on them"* (P19).

Nevertheless, not all participants appreciated the distortions in the projected display: *"It doesn't project like a square. Like you don't see it as a square. You see it like as a trapezoid"* (P1). Some participants found it **difficult to read** (P3, P13 & P16) from the projected display due to unfocused projection at a very small or large size. Other participants suggested that they were distracted while reading in a crowded street (P8, P14 & P20) and it was slightly inconvenient to find an even surface to project onto (P6, P8 & P18).

We did not observe any specific patterns among participants or across buildings in relation to where or how participants projected the POI-specific content onto the heritage building. On the two occasions when researchers observed some similarities, these were caused by the physical state of the POI (e.g., the façade of a POI was covered in scaffolding leaving only the door exposed which was then used as projection surface) or by the proximity, the lighting conditions around and the quality of the available surfaces.

Phone guide users also engaged in **scanning** and **pointing** gestures. For example, while the camera view was 'on', some smartphone users engaged in scanning gestures through the camera view. M9 chose to point the phone towards the surroundings to search for possible POIs as it made the whole activity more enjoyable: *"[the app] would have worked just the same if I didn't point upwards [...] [but] it would be less enjoyable if I wasn't actually searching around with the camera for these spots"* (M9). However, *phone guide* users only performed these actions occasionally, and the desire to do so declined as the walk progressed. Often, participants glanced at the building and then continued reading. M2 explained: *"whenever the thing [information] popped up, I would just read as I went, because I had the information with me, I didn't have to stop"* (M2). They further added *"I was [...] picturing it in my head [...] but I didn't feel [I] had to stop and look at the building"* (M2).

Furthermore, during the interviews, multiple *phone guide* users noted that they **looked but did not engage** during the walk: *"I was engaging in looking but that looking was more of trying to find something or looking through the phone. So, I was sort of disengaging with the surrounding area, I was focusing on phone"* (M6). Participants often read the information without moving closer to the buildings. The lack of physical engagement created a sense of distance between the individual and their surroundings: *"I felt a bit distanced as I am distanced from the actual thing"* (M1). This was also evident by the fact that 29% of *phone users* (vs. 42% projector users) oriented themselves in visual alignment with the buildings while reading the information, and only 19% (vs. 42% projector users) re-positioned themselves after stopping to be closer or further from the building to get a better view.

4.4 Social engagement and experience

For *projector guide* users, the display usage in public space triggered spontaneous social interactions with strangers on multiple occasions. However, users had mixed reactions. Several participants reported enjoying that the projector gave them the ability to **foster social interactions**: *"It was good when all these (people) are trying to ask me, what you are doing?"* (P20). For example, P9 exploited the projected display's potential to share their heritage experience with passers-by, by creating a large projection on a wall. P9 reflected that *"I used the wall of the building. I thought that was cool because other people [...] see it too, that could maybe foster some interest. Other people might be [...][thinking] what's this? That looks interesting; and they've actually got to read it as well"* (P9).

On another occasion, passers-by noticed P6 reading information on the projected display and joined in (see Fig. 12). During the interview, P6 commented: *"I have the power [...] I'm inspiring these new people to question and engage with what's going on"* (P6). By having the information embedded in space, users and passers-by were able to use gestures and movement to support social interactions. Even when a participant did not receive the attention of the others, they were *"really expecting or hoping that someone else will get interested. Look at me projecting. That would be really cool"* (P7). It is worth noting that, based on the drawings, these social interactions were often quite memorable for participants, as 5 out of the 21 participants who used *projector guides* depicted them in their drawings.

Other *projector guide* users reported feelings of **awkwardness** from standing out. For example, P1 expressed uneasiness: *"I don't think I would like to attract too much attention. I don't like people talking to me in the street randomly [...] if it was more discreet, it would be better for me"* (P1). A number of participants also expressed issues related to privacy: *"It's very annoying, because some people keep*

Figure 12: A passer-by noticed P6 reading information on the projected display (1). They proceeded to stand next to P6, joined the experience (2), and then more people noticed and joined (3 & 4). The engagement became more interactive with P6 guiding passers-by's attention and communicating the information.

looking at you while you're walking [...] you might say it's like they are interfering in a personal issue" (P6). Furthermore, P8, P11 and P12 explained that their personalities may be a reason for feeling uncomfortable: *"I would prefer to not explain things to them [passers-by] [...] but I can see that it might be because of my characteristics and not because of the nature of this device"* (P8). Nevertheless, P12 suggested that *"if more people had them (projector) or were using it and it was quite common thing, I would not be conscious about it"* (P12).

While *projector guide* users were getting the attention of passers-by, none of the 21 *phone guide* users had any direct interactions with other walkers. This often led to *phone guide* users feeling **alone and isolated**. M16 explained that: *"It made me feel like more aware that I was walking on my own, [...] because I was focusing on the phone and my surroundings so I wasn't really aware of the people around me"* and *"it felt pretty isolating in a way"* (M16). M19 also noted that *"if you talk about place I was engaged, but if you talk about people I wasn't"* (M19). Another *phone guide* user described how using the phone made them unavailable to the social dynamics of the street: *"makes me think of the people walking down the high street, which was kind of what I disappeared from because I was with the phone in the architecture. So, I think my engagement with the [social], that side of the street, disappeared"* (M9).

5 DISCUSSION

In this study, we investigate the potential of different display technologies to facilitate embodied experiences during outdoor heritage walks. Given that different technologies present specific features and that cultural heritage is a context where their effect on the experience had not been researched previously, we focus on understanding how different displays shape users' sense-making and experience in heritage walks. Our analysis allowed us to identify the affordances, strengths, and weaknesses of *phone and projector guides* (see Table 1), which can be valuable for designers of applications aimed at supporting embodied and experiential outdoor heritage walks. In the following sections, we discuss some insights and suggestions for design directions that we have gathered from our research, which can inspire future work in the field of designing mobile guides for outdoor heritage walks.

5.1 Design to change the user's attitude towards the technology

Our results indicate that *phone guide* users' behaviours were influenced by their pre-established habits of using smartphones while walking. Due to the apparent ordinariness of the task, they were frequently in navigation mode, and remained physically distanced from the heritage buildings, resulting in a lack of creativity and exploration. In contrast, we found that *projector guide* users were more inventive, explorative, and aware in their use of the device. However, this may be related to the novelty of employing a technology they were unfamiliar with. Consequently, their attitude and approach to the activity were more aligned with performing a 'special', non-routine task.

Based on our findings, we suggest that designers of mobile guides for heritage walks should consider leveraging the users' familiarity or unfamiliarity with the chosen technology. One way to accomplish this is by disrupting the users' familiarity with the device, thereby prompting a new rather than an already established behaviour. In our study, this was achieved by using portable projectors, a device that users were not particularly familiar with. Alternative ways to exploit the users' familiarity with an artefact can be explored. For example, Kidd describes 'The Lost Palace' experience, where a mocked-up burned torch is used as a handheld device to conceal the technology [33]. As a result, the technology recedes into the background, enabling participants to concentrate on the artefact's performative and narrative potential, and thereby engage in a deeper exploration of the site and its history. In general, whether through familiarity or unfamiliarity, mobile guides that encourage embodied and spatial engagement have the potential to support meaningful explorations of historical contexts.

5.2 Design for an embodied relationship between technology and the user

During our study, we observed that participants using both display modalities exhibited a desire to perform body movements to enact exploration. However, the frequency of occurrences of such enactments was higher among *projector guide* users. During the walks, we observed that participants intuitively controlled the projector and its beam as an extension of themselves to reach, touch, and interact with the surroundings. As the device and user came into an embodied relation [26], users were able to focus their actions

Table 1: Summary of key findings.

Walking patterns and behaviour
• **Phone guide users** were often engaged in purposive walking (focused on reaching a destination), which resulted in missed opportunities to make their own observations, discoveries, and connections with the site. Moreover, the familiarity with the activity of walking with a mobile phones made the heritage walk appear like a routine task. • **Projector guide users** were engaged in exploratory walking, which resulted in more time for absorbing and processing the multisensorial information received from the whole street. In addition, they were more inventive in their use of the device when exploring the site.
Awareness and feelings of "being there"
• **Phone guide users** had a narrow field of focus on specific areas of the street. They remained in their own 'bubble' instead of 'being-there' on the street and paying attention to the rest of their surroundings. • **Projector guide users** maintained a greater awareness of their physical and social surroundings while on the street, even when reading information.
Embodied engagement and meaning-making
• **Phone guide users** used the device as an item to 'interact with', which led to distance and disengagement with the surroundings and heritage buildings, but facilitated mental connections between information and the site. • **Projector guide users** used various gestures and movements to bridge the gap between the digital and physical worlds during the walk. The device became an extension of their bodies and often enabled them to appropriate the street and heritage buildings as places for exploration, discovery, and play.
Social engagement and experience
• **Phone guide users** reported that during the walk they felt alone or 'isolated'. • **Projector guide users** had increased opportunities for social engagement with strangers. This led to a sense of satisfaction for some, but others reported feeling uncomfortable about attracting attention.

towards the physical surroundings instead of the device. Such an embodied relationship was one of the factors that motivated and facilitated expressive, creative, and playful actions of exploration among *projector guide* users.

Conversely, the *phone guide* did not support such actions of exploration since the smartphone remained a device to 'interact with' instead of becoming an interactive artefact through which people could mediate and express themselves. This may explain why *phone guide* users gradually abandoned the actions of framing as the walk progressed. Since *phone guide* users were able to see everything on a screen in their hand, it negatively influenced their desire to walk closer to the heritage building, turn towards it to view it properly, or sometimes even stop. In fact, the *phone guide* acted as a barrier that interfered with the formation of connections between users and the heritage site.

Thus, designers of mobile interactions and technology for cultural heritage would benefit from designing not only interference-free interactions, but conceiving artefacts that can act as a 'medium for interaction' with the heritage site (much like a game console) instead of as a device to 'interact with'. The 'Digital Binoculars' mentioned in Ciolfi's work [11] is an example where the device becomes a medium to explore the site, rather than only an object to interact with. Similar interactions can be developed to reward embodied actions where users could be provided with information based on their orientation, movement towards, proximity to, or time spent near a site.

5.3 Design interactions that bring the surroundings into play

In our study, the actions and reactions of *projector guide* users show that they were attentive to their physical and social environment, affected by their surroundings and responsive to different elements and events on the street. The *projector guide* brought the surroundings into play and enabled users to momentarily alter them by projecting wherever they wanted. The display was continuously embedded and visible in the physical surrounding. Every movement of the users displaced the projection and, in-turn, became connected with the space. In contrast, even though *phone guide* users were also interested in discovering heritage buildings, they were often unaware of other aspects of their physical and social surroundings and frequently remained in their own 'bubble'. The screen of the *phone guide* acted as a barrier between body and space, interfering with the natural coupling that exists between people and their surroundings. This led to missed opportunities for users to make their own observations, discoveries, and connections with the site.

Based on our findings, it could be argued that the *projector guide* enhanced participants' aesthetic experience of the heritage site by facilitating a more immersive walk which entangled their actions and perceptions with the surroundings. It also helped anchor their experience to the physical and social aspects of the space, enhancing users' sense of 'being-there'. In the 18-19th century, travellers used *Claude glasses* [44], a portable technology, to see landscapes. This

convex mirror with a dark tint simplified the landscape's colour and tone range, distorted perspective, and framed it like a painting. Tourists used it by turning away from the scenery and looking at the altered reflection in the mirror. Thus, *Claude glasses* connected visitors' bodily actions to their surroundings, changed their perception and aesthetic experience of the landscape. A more recent example is the 'Wandertroper' [46], which uses the location responsive sound to encourage and enhance the experience of exploratory walking. The location responsive sound explicitly and continuously interlinks the users' body movement to the surroundings. The generative sound alters the sonic perception and the experience of the environment. Based on our findings and other discussed examples, we encourage developers to conceive mobile interactions that bring the surroundings into play by explicitly intertwining users' actions with the physical/material and social aspects of the site when designing technologies to augment outdoor heritage experiences.

5.4 Design for supporting co-located interactions with strangers

Designers and researchers in museum and heritage contexts have been studying and exploring ways to support social interaction among group visitors to enhance social experiences during the visit [36, 54, 57]. However, in line with previously reported findings [9], we found that chance social interactions with passers-by (e.g., locals, other tourists) play a significant factor in the overall experience of heritage tours. Thus, there is a need to create opportunities and support such chance social engagements even during individual outdoor heritage walks.

As suggested by Jarusriboonchai et al. [29] and observed in our research, it is important to share some information about the users' activities with co-located individuals to facilitate co-located interactions. In our work, the projected display acted as a social display that invited such interactions and created opportunities for 'chance-interactions' with passers-by.

Carr et al. [7] suggest that when people visit public spaces, they want to observe, interact with, and meet new people. Hence, it is understandable that most of our participants were happy with such social interactions, which also became one of the memorable aspects of their walk (as reported in interviews and drawings). On the other hand, – not surprisingly, – the private nature of the display resulted in most *phone guide* users feeling alone during the activity as they did not observe people or interact with them while walking.

Nevertheless, since outdoor heritage sites are often public spaces, people visit them for a variety of reasons (e.g., tourism, exercise, dog walking) [45]. What provides a meaningful experience for one type of visitor might badly impact another type of visitor. Consequently, it is important to carefully consider what type of augmentation is appropriate for each context and visitor. During our study, some users did not perceive the use of the projected display as a social display positively. They felt uncomfortable due to the attention they received from passers-by. This is explained by Goffman's proposition that in any social context, people are constantly conscious of their appearance to others and the impression they are giving [18]. Some participants did suggest that while using the *projector guide* in a public space, they were concerned with how strangers perceived them for walking with a projector. However, they suggested this feeling of discomfort may diminish when the device is used in a group. Such reactions towards the use of public display was also observed by Jarusriboonchai et al. [29]. Thus, it is an important factor to consider while designing technology to support social interactions as it may affect users' experiences and their motivation to adopt the technology.

Additionally, outdoor heritage experiences are influenced by cultural aspects, and as diverse visitors can interpret these differently, their behaviour can vary too. Therefore, when designing mobile guides for public spaces, cultural appropriateness should also be carefully considered.

5.5 Reflections on choosing appropriate technology for mobile guides

When selecting a portable technology for a cultural heritage context, a common concern is the practicalities of its implementation. *Phone guides* appear to be quite suitable, since organisations can benefit from the fact that the majority of users own and are able to bring their own device. For users, phones have good display quality, are convenient to carry, and can be used anywhere. From a curatorial perspective, they are suitable for supporting information-focused interpretation. More affective engagement can be added by employing techniques such as storytelling, pervasive gaming, and presence-based information delivery [14, 40]. Nevertheless, the devices' displays have a distracting influence on users' attention to the surroundings, which is a significant drawback, especially during outdoor heritage walks [31, 35].

Another factor which influences the selection of technology is its trend and perceived novelty. Researchers have studied the use of smart-glasses and headsets in museums and outdoor heritage sites, not only for their ability to deliver information without distracting the user from the surroundings, but also because such technologies are perceived as novel and attractive for visitors [39, 43]. Nevertheless, despite being enjoyable and fascinating to use, the implementation of wearable AR faces many challenges in its current form (See Section 2.2), which makes its wider deployment a major challenge.

Through our study, we have found that using smartphones can negatively impact visitors' lived experience and social interactions in outdoor heritage sites. AR glasses, like smartphones, also show visual information in a private way. As a result, we anticipate that AR glasses will have a similar effect on users' behaviour as smartphones do. In their current state and unless they are networked, AR glasses may be unable to facilitate chance social interaction or encourage individuals to walk closer to objects and buildings. With this in mind, we suggest considering handheld projectors, or design other such technologies that provide similar features for outdoor heritage experiences. Although handheld projectors are not novel *per se*, our findings suggest that users perceive *projector guides* as novel and to be an easy-to-use technology, which evoked positive responses during the walk.

We acknowledge that, like other technologies, portable projected displays, are not the ideal solution – with their primary limitation being their ineffectiveness under daylight conditions. Nevertheless, as a study instrument, it allowed us to explore the effects of specific display characteristics that are not commonly available in alternative technologies, such as the ability to blend information with

the environment, and to allow shared views by multiple people. Although projective technology is not new from a technological standpoint, our results show it might have an important role in supporting heritage walks because it enables users to form personal interpretations based on embodied, aesthetic, and collective experiences.

5.6 Limitations and future work

Our work provides insights into the effects of different display modalities on embodied experiences and social interactions during outdoor heritage walks. However, we are aware that our study has its limitations. The three main ones are reported below. By acknowledging them in combination with our results, these limitations will inspire future work.

Predefined path and static content. In this work, we only studied user experiences in a predefined straight path using static content (text and pictures). This allowed for easier planning and testing of the information on the location aware application. It also helped us keep the conditions consistent across the walks and draw conclusions on the effects of the display technology alone. However, it is reasonable that these characteristics may have influenced users' behaviour and their overall experience. Considering the results of this work, it would be important for follow up work to also investigate the impact of unplanned routes as well as different content design strategies on the overall relationship between the user and the site.

Heritage visits as a group activity. Although heritage visits are frequently enjoyed as a group activity with family or friends, our study was limited to individual users. This was due to the exploratory nature of the study and the private usage of smartphones. In future work, We intend to investigate the effects of using mobile guides during group walks in the future, as well as how they affect group dynamics and user experience.

Participants. Finally, another significant limitation of this study was that participants were not tourists (the typical target audience for such experiences). This was due to the challenges and ethical implications of finding and recruiting tourists while in a public space. Nevertheless, our participants had varying levels of familiarity with the street, which contributed to a range of interactions and comments. Further studies could be conducted with visitors who are not already familiar with the selected site. Similarly, we anticipate that the elderly and children may behave differently while using *projector guide* in public space. Studying population from different age-groups may lead to different visitor behaviours and provide a broader understanding of the influence that different display modalities have on different users in the context of outdoor heritage exploration.

Technology. The disadvantage of *projector guides* is that they can only be used in the evenings or in low-light conditions. AR glasses, on the other hand, can overcome this limitation despite their small displays. Currently available AR glasses (designed for casual and outdoor use) have small displays but are rapidly evolving and gaining more functionality and commercial feasibility. Thus, future studies could compare AR glasses with the *projector guides* and contrast their effects on users' walking habits, group experiences, and embodied experiences of the heritage walk during the day.

6 CONCLUSION

In this paper, we have investigated the effects of two display modalities (smartphones and portable projectors) on embodied experiences during outdoor heritage walks. To do this, we conducted a field study with 42 participants using the two modalities on an urban high street. Our findings suggest that projected displays enhance spatial, social, and somatic awareness during the walk. They also encouraged embodied engagement and meaning-making with the space, and facilitated aesthetic experiences. Moreover, it created opportunities for social interactions with strangers. Based on our results, we discuss some insights and possible design directions for those working in the cultural heritage sector. Our observations contribute to a broader, more generalised discussion on how to design mobile guides in the context of cultural heritage that goes beyond information consumption and supports lived experiences and connection with the past.

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