Shaking the Dead: Multimodal Location Based Experiences for Un-Stewarded Archaeological Sites

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ABSTRACT
We consider how visits to un-stewarded historical and archaeological sites - those that are unstaffed and have few visible archaeological remains - can be augmented with multimodal interaction to create more engaging experiences. We developed and evaluated a mobile application that allowed multimodal exploration of a rural Roman fort. Sixteen primary school children used the application to explore the fort. Issues, including the influence of visual remains, were identified and compared with findings from a second study with eight users at a separate site. From these, we determined key design implications around the importance of physical space, group work and interaction with the auditory data.

Author Keywords
Auditory Display, Un-stewarded Archaeology, Audio Augmented Reality, Location Based Experience

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*Interaction Styles*

INTRODUCTION
The Antonine Wall (www.antoninewall.org), running from the west to east coast of the central belt of Scotland, represents the most northern settlement of the Roman Empire in Britain. In 2008 it was designated as a UNESCO world heritage site (whs.unesco.org). This places it on the same level of international historical and cultural importance as sites such as the Sydney Opera House and the Great Wall of China. Yet, unlike those sites, few obvious visual physical remains exist, and those that do are spread over several hundred kilometres of rural countryside. As such, although parts of the wall are accessible to the public, they are unstaffed and have no other facilities such as visitor centres. Any archaeological finds that were uncovered have been moved off-site to museums many miles away. We term these as un-stewarded archaeological sites. A concrete example on the Antonine Wall is Bar Hill fort.

Located 0.8km outside of the town of Twechar, Bar Hill is one of the forts spaced along the wall from which soldiers would live and control access to Roman territory. One hundred meters long on each side, the fort contains several buildings, including a Principia (administration block), bathhouse, workshop and several barrack buildings (see Figure 1 top left from [11]). However, only visible remains of the Principia and bathhouse (Figure 1 (top right & bottom left)) can be seen by visitors. As there are no staff, only a few signs illustrate the importance of the site (see Figure 1 (bottom right)). Many finds have been discovered at the fort, but all have been removed to museums in the surrounding area. Bar Hill is not alone in this. Of the five world heritage sites located in Scotland, three are in rural environments as are countless other rural sites of national importance, such as the many battlefields that exist across Scotland. For visitors, understanding such sites, and how they worked when occupied, is challenging when compared to stewarded sites, such as open-air museums or country houses.

Working with the Hunterian Museum and Historic Scotland, we have been investigating how visits to un-stewarded archaeological sites can be made more engaging and informative by means of location-based multimodal mobile applications. Our goal is to better understand the challenges of supporting such visits, and develop multimodal techniques for their effective digital augmentation.

RELATED WORK
How to augment the physical world with location-based digital information is not a new problem. Location-based Mixed Reality Environments (MREs) [3] overlay digital information on the physical world. Examples of studies in this area range from artistic experiences [14] to understanding and learning about the physical environment [3, 9]. However, the majority of previous research has been undertaken in urban environments, either on built-up city streets [16] or in small pockets of nature in the city [3]. Almost no research has considered a rural environment in which many un-stewarded archaeological sites are found [4]. However, previous work in urban environments has shown that the physical space exploited has a strong influence on user experience. In CitiTag [16], a location-based game where users had to tag (or eliminate) players of the opposing team, Vogiazou *et al.* found that the way users played the game varied depending on the environment. In a grass area of a university campus, players behaved in a very action-oriented way. On the city streets players were more creative, exploiting the physical environment to improve performance in the game, such hiding in a bus shelter to deliberately loose GPS and avoid being tagged.

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Figure 1. Archaeological map (top left) of Bar Hill fort. Few physical remains exist, only the bathhouse (top right) and the Principia (bottom left). Only signs (bottom right) provide information.

An additional issue surrounding location is the existence of a prior relationship between the virtual and physical environment. Although the environment played an important part in how users played CitiTag, the game could have been played anywhere: there was no prior relationship between the game and the environment in which it was played. This arbitrary overlay of a virtual world onto a physical space is common. For instance, Savannah [3, 8] allowed users to roam a virtual savannah as a Lion, and allowed them to kill prey and otherwise explore. Here, the virtual environment was mapped to an empty grass park. This was noted as both a benefit, by allowing users to easily see each other and collaborate, and a cost, as it did not resemble the real savannah environment. More recent studies have more closely connected the virtual and physical worlds. Anderson *et al.* [1] have begun to investigate how using Augmented Reality to overlay historical photographs onto buildings can provide an insight into the history of a city centre. *Riot! 1831* by Reid *et al.* [9] strongly correlates the virtual and physical space in a historical scenario. Users, equipped with GPS units, mobile devices and headphones, walked around a city square in Bristol. Audio vignettes of events during riots in the square were played as users moved between pre-determined zones. The authors remarked on the strong influence the physical environment had on the immersion experienced by users. Archeoguide [15] was amongst the first systems to present visual augmented reality reconstructions of sites through tablet based computers, strongly correlating the virtual and physical worlds. This was taken further in the *Explore!* system by Costabile *et al.* [6] which allowed exploration of the archaeological ruins of Egnathia in Italy. Users equipped with mobile devices had to explore the ruins as teams, completing a number of missions under the direction of a "games master". Whilst Costabile *et al.* considered that the archaeological site may be unstaffed, the game still required one person to act as the games master to "run the system", and for all devices to be connected to each other over a network. This is not possible to guarantee in rural environments with poor cellular reception, and such dedicated infrastructure is not practical at un-stewarded archaeological sites. The quests carried out by users could include interaction with multimedia feedback, and the comparison of the archaeological remains with a 3D virtual model displayed on the screen of the mobile device. However, the site used by Costabile *et al.* contained a uniform quality of visible archaeological remains covering a large area of the site. This is unlike the irregular quality and visibility of remains at an un-stewarded site such as Bar Hill. More generally, un-stewarded sites lie somewhere between the empty field used in Savannah and the uniform quality of *Explore!*. Whilst in un-stewarded archaeological sites there is a clear prior relationship with the environment, the clarity of this is not always constant. Areas with clearly visible archaeology are likely to influence users differently than when no obvious remains exist. It is unclear from current research what these influences would be.

The work discussed previously required users to interact with a GPS-enabled mobile device to track both user location and allow interaction with the virtual environment. Work has sought to more closely bridge the physical and digital divide by incorporating tangible technologies. Stanton *et al.* [12] investigated how the history of Nottingham Castle could be experienced. Participants were given clues, on paper, to find objects within the castle, of which they could take rubbings or make drawings. The paper was then augmented with RFID tags, and could be used in conjunction with a tangible controller in the castle gatehouse to interact for video and audio material related to the drawings and rubbings. Work, such as the digital periscope [17], has extended the use of proximity sensing to the the outdoor environment. Physical electronic devices located in a forest as well as RFID-tagged objects in the environment, were employed to allow exploration of a woodland habitat. Whilst the work of Stanton *et al.* [12] considered how historical information on a largely ruined castle could be conveyed, and Wilde *et al.* [17] considered the exploration of a more rural environment of woodland, both need curation. This need for curation extends to the work of Ballagas, Kuntze and Walzs' [2] REXplorer system. This allowed objects (such as statues) to be interrogated through gestures, using a custom mobile device with spoken audio feedback provided by a speaker embedded within the device. This helped provide a sense of immersion by blurring the border between the digital and physical worlds. However, such approaches still required special equipment to be hired, supported and maintained (e.g. from a tourist information office). Such approaches are therefore unsuitable for remote un-stewarded sites, where no staff exist. Therefore, any technology needs to be supplied by the end user rather than an outside organisation.

A final area of relevance concerns the form in which digital information is presented. Whilst creating a virtual 3D model that can be overlaid on a live video feed of the real environment is a common approach [1], it can isolate the user from the environment that they are attempting to interact with. As noted by Carrigy *et al.* [5] in the evaluation of a location based game: *"Paradoxically, the game encourages looking at the screen more than the surroundings"*. A means

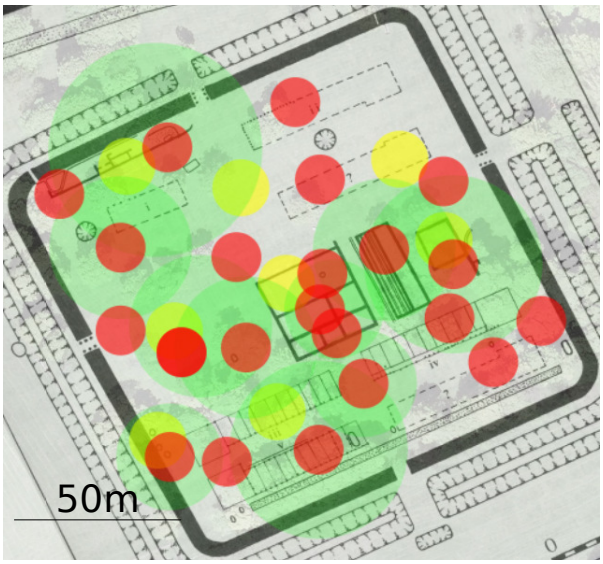

Figure 2. Number and distribution of Romans (yellow), sound effects (green) and finds (red). Circle radius indicates the auditory boundary for sound effects and activation zone for finds and Romans.

to overcome this is through the presentation of audio. Facer *et al.* [8] notes the importance of audio to create the sense of being in a physical manifestation of the digital world. The audio sound garden of Vazquez-Alvarez *et al.* [14], which collocated virtual sounds sources with statues in an urban park, found that engaging experiences which augmented the environment, rather than replacing it through visual device interaction, could be achieved.

Whilst the work discussed shows promise in allowing users to explore un-stewarded sites and gain understanding from them, the unique challenges of such sites [4] require us to understand how these approaches work. Whilst rural sites may provide high-quality GPS signals, they are unlikely to have good (if any) network access. This excludes the centrally controlled collaborative approaches of Costabile *et al.* [6], or the eavesdropping techniques of *Sotto Voce* [13]. To what extend are these needed and how might we provide them? The role of the patchy physical environment, and how it affects interaction is also unclear.

VIRTUAL EXCAVATOR

To begin investigating the issues outlined in the previous section, we developed an application designed to support users when visiting Bar Hill fort. Virtual Excavator runs on the Apple iOS platform. Its design was informed by two visits to both Bar Hill and Rough Castle fort, another fort on the Antonine Wall. We were accompanied by park rangers from Historic Scotland and Falkirk park service. Both are responsible for maintenance of sites along the wall (e.g. creating signs, etc.). During these visits we observed that understanding of context was the key reason for visiting the site. This supported understanding of the importance of the site, the activities of the people that lived there and the purpose of uncovered finds. Our application design was based on our prior work with urban Sound Gardens [14] and was designed as an exploratory environment, where it was the physical movement of the user, rather than the system, that drove discovery. This means that the user will be in the physical context that digital information refers to (e.g. the location a physical object was found) whilst learning about it. The visual interface allowed users to locate themselves on an archaeological map of the fort taken from [11] (see Figure 1 (top left)). In addition, to help fill the gaps in the visible archaeology, we employed a rich, dynamic, spatialised auditory environment that could draw users to different parts of the site. We used GPS and the inertial sensors (magnetometer and gyroscopes) built into the device to update a 3D sound environment to reflect the position and orientation of the user. This meant that sounds could be fixed to locations in the environment, allowing the user to walk around the sound sources. Two types of audio information were presented in our application: Romans and sound effects. Each individual sound was centred on a physical location. Sounds got quieter the farther the user moved from their location, and each had a set auditory boundary beyond which the user would not be able to hear it. This allowed for a more realistic auditory environment than with existing "triggered" audio approaches [9].

Sound effects were used to communicate activities in the environment. These were used both as information about activities in the buildings that made up the fort (e.g., the sound of hammering in the workshop, or water and splashing in the bathhouse) and to provide a general feel of activity (e.g., the sound of footsteps trudging down to the bathhouse or the sound of a horse and cart passing through). We employed them as a means to draw users around the site, pulling attention to those areas where no visual archaeological remains existed. Sound effects were played on a loop, but were altered to ensure that this looping appeared natural, e.g. adding a few seconds of silence after the sound of footsteps. Auditory boundaries were set individually for each sound effect based on informal testing.

Romans represented people who would have lived and worked at the fort. We envisaged these to play a similar role as re-enactors do in stewarded sites: talking to visitors and explaining what would have been happening. The personas for the Romans were derived from archaeological excavation reports [11] and consultation with Roman experts at the Hunterian Museum in Glasgow to ensure their authenticity. Personas were recorded by professional actors. Unlike sound effects, the Romans were not played on a loop, and were started when the user stepped into an activation zone 10m from the location of the Roman. In addition, an image of the Roman, as well as a transcript of the Roman's speech was displayed on the iPhone screen. As with the sound effects, the Roman became quieter as the user walked away, stopping when the user crossed a 20m auditory boundary from the Roman location. Users could also manually dismiss the Roman, causing the sound to stop immediately. The number and location of Romans, sound effects and their respective auditory boundaries are shown in Figure 2.

Another issue to emerge from our earlier visits to the forts was how to represent archaeological finds and their contexts. At stewarded sites finds may be able to be retained in context (e.g. a stately home may retain the dining room as it was 200

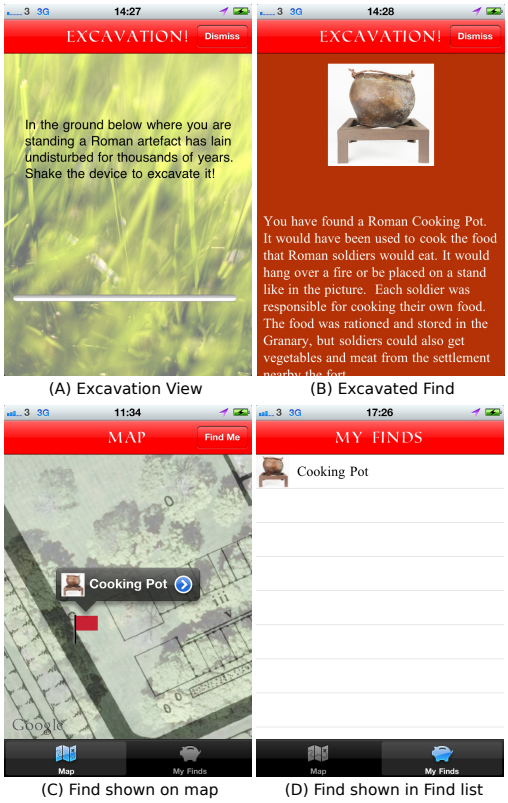

Figure 3. Illustration of excavation in Virtual Excavator.

years ago) or housed in a nearby museum [12]. In the case of Bar Hill fort, finds are distributed amongst many museums that are themselves geographically separated. Trying to identify a clear understanding of the finds, the relationships between them and the physical environment can be difficult. Museums make considerable effort in trying to bridge this gap by recreating parts of the original context in which to exhibit finds: e.g. recreating an Egyptian tomb with grave goods. We implemented the reverse of this approach by placing virtual finds back into the real context. Finds were geolocated in the physical environment and triggered a vibration on the device as the user walked within 10m. To uncover the find the user had to shake the device (to simulate something of digging an find out of the ground). Each shake caused a scrapping sound to be played. Once uncovered, the find details were presented. The find could be viewed at any time via the map or the finds list (see Figure 3).

STUDY 1

Because there is little understanding of interactive experiences in the context of un-stewarded archaeological sites, particularly when incorporating spatialised auditory displays, we wanted to compare our findings with a more conventional approach. We created a second application called Site Guide. Site Guide resembles a standard tour guide application, and provided access to the Romans and finds from Virtual Excavator. We retained the same visual UI as Virtual Excavator, and when launched, Site Guide presented a populated map (with colour coded flags to represent Romans and finds) as well as a fully populated finds list. By tapping the flags users could see the same views for Romans and finds as

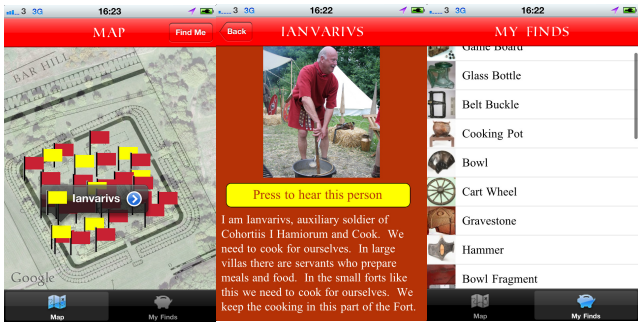

Figure 4. Site Guide gave immediate access to all Romans and finds (left and right). Roman dialogs (center) provided a button to play speech that was automatically played in Virtual Excavator.

the Virtual Excavator users. We added an additional button to each Roman view to allow users to play the audio of that Roman. However this was not played in the 3D environment, and walking away did not affect the volume or direction of the Roman. Figure 4 illustrates the key changes.

We evaluated both Virtual Excavator and Site Guide with a group of 16 primary school children aged 11-13 who took part during a class trip to Roman Scotland. Participants spent just over an hour in total at Bar Hill fort. We ran the participants in two groups of eight. In each group, four participants were randomly assigned to use Virtual Excavator and four to Site Guide. Each participant was given ear buds and an iPhone running the appropriate application, which was demonstrated before starting. Participants were then instructed to explore the fort. All started at the same location: to the right of the Principia. The experimenters followed, video recording each group. We set a maximum exploration time of 15 minutes for each group of eight. We did not set a minimum time and participants could stop whenever they wanted. Other than one instance caused by a device fault, none of the participants stopped early. We also logged significant amounts of data from each device, including GPS traces and a log of participant interaction with the application. During the exploration there were several older, secondary school pupils (approx. 17-18 years old), who were taking part in a mentoring program with the primary school pupils. They were not directly involved in the study, but did interact and provide assistance where required.

Results

We employed a framework approach [10] in analysis of the video, interview and logging data. Initial codes were based on observations during the study. Three key areas on the exploration of un-stewarded sites were identified.

Dominance of Physical Archaeology

One key feature that emerged from the use of both applications was the importance of the visible archaeology. All GPS traces generated by users of Site Guide could be contained within a bounded area of 1464m^2, and for Virtual Excavator within a bounded area of 1240m^2. These areas are of similar size. An outline of the GPS traces from both applications (see Figure 5) confirmed our observations during the study that exploration was bounded to the area surrounding the Principia. Along with the bathhouse, this is one of only two

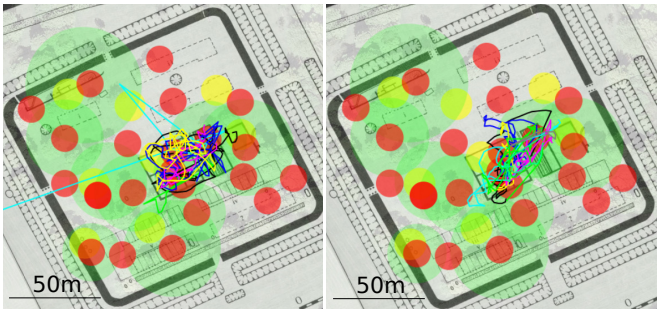

Figure 5. GPS traces for all participants overlaid on the map for Virtual Excavator (left), and Site Guide (right).

areas of the site where significant visual archaeological remains still exist, and one cannot be seen from the other. The video recordings showed frequent examples of participants walking on the walls outlining the Principia. There were two identified reasons for this. Firstly, participants were trying to orientate themselves in the environment (i.e. understand the relationship between the map on the device and the physical remains). The scarcity of the physical remains and the regular shape of the fort made this challenging. By walking around the perimeter and watching the dot, indicating the current GPS location on the map change, participants hoped to understand this relationship. Secondly, participants used the physical outline of the Principia as a path, using this to systematically explore the area and locate finds.

Although we observed participants wander from the Principia, they did not go far and quickly returned. In some cases participants were trying to cause the location indicator on the map to move and again understand how the map related to the environment. We cannot be sure how many deviations from the Principia were due to determining orientation and how many were due to trying to locate finds. However, the archaeological map used in both applications showed that buildings existed in all directions from the Principia (see Figure 1), and that walking in any direction would likely lead to finds or Romans. In the initial demonstration for participants using both Site Guide and Virtual Excavator we encouraged them to move around, yet they did not move far. We hypothesise that the physical remains constrained user exploration and we will return to this in Study 2.

Whilst the physical remains constrained the exploration of users, it also highlighted the importance of a location-based approach. Site Guide data also supported this. Here, participants could select any find or Roman, without the need to physically move to its location. However, Romans and finds located within the area where participants moved (see Figure 5 (right)) were more often selected. Indeed, most of the finds and Romans outwith this area were never selected. This was supported in the debriefing session after the exploration of the fort was completed. When asked about what they had found out or could remember, participants with the Site Guide only mentioned finds near the Principia. From the video data, we also observed users of Site Guide trying to get to the location of the find being viewed. The following extract illustrates two Site Guide users trying to reach the location of a bowl they are viewing (see Figure 6).

Figure 6. Site Guide users try to locate the physical location of a find.

P5 & P6 are standing next to each other interacting with their respective devices
P5: "Go back in!"
P6 looks over at P5's device. P5 tilts the device slightly toward P6.
P5: "What's that?"
P6: "A bowl"
P5 (overlapping with P6): "An eating bowl"
P6: "I've already had that"
P6 (walking around P5): "So if I'm there."
P5 turns and walks towards the south, P6 walks in the opposite direction, turns around and walks toward P5.
P6: "What's the (?), is it this way or that way."
P5 Runs around the Principia perimeter whilst P6 turns 90 degrees on the spot several times. P5 turns and begins cutting through the Principia towards P6. They meet slightly below the Principia (closer to the location of the bowl) and compare devices before wandering off in different directions.

We conclude that the physical environment guided the users' selection, with finds nearby being more relevant than those that were physically distant.

Interaction with Finds and Romans

In understanding the site both Romans and finds are important. Romans contextualise finds, illustrating how they were used (e.g. a Roman cook or blacksmith), whilst finds provide detail and complement the Romans (e.g. a cooking pot or hammer). The popularity of finds vastly outweighed that of Romans. When debriefing, we asked participants what was the most enjoyable part and what they remembered about the experience. Irrespective which application was used, all expressed a preference for finds being most important.

In contrast, the logged data showed that Romans and finds were equally accessed by participants. With Site Guide we logged 52 occasions in which participants had accessed one of the 25 finds, compared with 16 occasions for one of the 8 Romans. For Virtual Excavator such a comparison is less meaningful, as users could only interact with finds and Romans in the area where they walked. Because participants did not move far from the Principia, the number of Romans and finds were smaller (7 interactions with Romans and 9 finds across all log files). In addition, in order to avoid Romans reactivating as soon as they were dismissed (or auto dismissed due to a GPS jump), once played they were added

to a "blacklist" such that the user would have to walk out of the activation zone plus ten meters before the Roman could be triggered again. If the user never stepped out of this activation area, the Roman would never be replayed. From the video there is evidence that this caused participants to think the application was broken as they couldn't hear anything: *"It's not working, I couldn't hear a single thing, I found two but then..."*. As participants stayed within the Principia, this limited potential interactions with content.

Analysis of the time spent interacting with Romans yielded variations between Virtual Excavator and Site Guide. The log files showed that participants with Virtual Excavator listened to each Roman for an average of 31 seconds. With Site Guide each Roman was listened to for an average of 36 seconds. Therefore the entire speech, lasting 45-50 seconds, was rarely heard by any user. Participants with Site Guide tended to be more tolerant and interested in the Romans. On several occasions they listened to the speech again or compared it with other users of Site Guide, and also talked about the Romans they 'met' during the debrief, something that users of Virtual Excavator did not.

We have less evidence, other than the lower average time, to support how participants with Virtual Excavator interacted with Romans. The data suggest the time users listened to the Romans dropped substantially after the first encounter, but data are not consistent enough to make claims. Our hypothesis is that users viewed the Romans as an interference in finding finds, not helping users in this, they were ignored. More data of user-Roman interaction is required to illuminate this. We return to this point in Study 2.

Group Interaction

Despite the lack of finds uncovered by participants with Virtual Excavator, video recordings show that participants engaged in collaborative and competitive behaviour, confirming their preference for finds rather than Romans. They treated the discovery of finds as a "treasure hunting" game. Diamantaki *et al.* [7] report that games can often emerge naturally, and it may be that the lower popularity of Romans was that they did not fit well with the users' objectives, as Romans could not be "collected" and added to a list in the same way as the finds. Participants with Virtual Excavator would explore independently, but join up for a few seconds to compare their finds, similar to the way in which two travellers on a road would pass the time of day when they met:

P1 standing still looking at her device.
P2 approaches, stops and looks at P1's device screen.
P2 (walking behind P1), "where did you find these all?"
P1 & P2 begin walking in the same direction
P2: "I kept on walking everywhere."
P1 diverges and walks along the Principia wall whilst P2 continues on the original heading.

The short sporadic nature of collaboration was common through all interactions with Virtual Excavator. Participants explored alone, but with clear short instances of interaction with others. We also found that participants would engage in "pack" hunting: grouping together for a few seconds to try to locate the centre point of a sound effect in the hope that a find (which was often the case) would be at its centre. In the following example (see Figure 7), four participants try to locate the centre of the sound effect and thus a find:

Figure 7. Virtual Excavator users formed "packs" to locate finds.

P1 & P2 are walking away from the Principia in the same direction, but not together.
P1 stops, turns to P2. "I've got it!"
P2 runs to P1's location. Both begin to walk slowly in the direction of P1.
P3 & P4 begin walking together toward P1 & P2
As P3 & P4 approach, P1 turns around with the device in her hand: "it's over there"
All participants start walking in the indicated direction.
P3: "they've found three things".
All participants stop at a stone. P3 mounts the stone, turns and walks away.
The rest of the group begin to move off in different directions.

The previous example is at the more obvious end, but there are also occasions where participants would "stalk" each other. One participant would follow another, sometimes at a distance, in the hope that if the user found something, he or she could move in and excavate the same find.

An important final observation about both groups of participants was that of showing off their finds. This happened more towards the end of each session, where participants tended to group with their friends and the older mentors. Participants would then boast about the number of finds they found. In all cases the importance of finds, and getting as many as possible, was a clear motivational goal.

Other than showing off, there is no evidence that the participants with Site Guide engaged in competitive behaviour. Their collaboration was much more about comparison and reflection (e.g. the earlier transcript of participants trying to determine the location of a bowl). The behaviour exhibited by participants using Virtual Excavator may have been amplified by restricting themselves to the Principia area, limiting the number of finds that could be excavated.

Understanding of the Archaeological Site

Due to the limited number of finds and Romans that were accessed with Virtual Excavator (caused by the limited physical movement across the site), there is less we can say about how well the participants understood the site. Facer *et al.* [8] note that reflecting on an experience is important in understanding it. There were short snippets of this during the debrief when we asked participants collectively what they remembered. Some participants were able to link a shoe found in the well with a young female Roman who was nearby. During lunch at a local museum, which contained finds from the site at Bar Hill, the participants were able to handle a selection of finds. Several identified the finds as those they had "found" at Bar Hill. This suggests that participants were able to gain some understanding of the site.

Discussion

The results of our study at Bar Hill support the notion that audio augmented reality can be used to provide interesting visits to un-stewarded archaeological sites and provide engaging activities that users enjoy. There were clear variations between Virtual Excavator, that used a spatialised auditory environment, and Site Guide. Participants with Virtual Excavator exhibited more game like behaviour, regarding finding finds as a challenge and something to be collected, much more than Site Guide users.

There are several guidelines that can be draw to allow developers to implement solutions for physical exploration. However, these would have limited impact without clearer understanding of the issues raised in the evaluation. All of the Virtual Excavator participants limited exploration to the visible on-site archaeology. This raises two points. Firstly, why? We hypothesise the visual remains of the Principia enacted a strong pull on users, meaning that they did not feel it useful to explore outside that area, in spite of the clear desire to discover finds. We used sound effects in the form of environmental audio to indicate the distance and direction of interesting things, and from the earlier transcript on "pack hunting" participants understood this role of the environmental audio. However, they did not use this knowledge to discover finds outside of the obvious visual remains. Secondly, and related to the limited physical area, was that users of Virtual Excavator interacted with relatively fewer finds and Romans, limiting our understanding of their interaction. In order to consider these issues we carried out a second study.

STUDY 2

We used only Virtual Excavator in the second study. As we wanted to understand how the visual remains affected exploration, we carried out this study at a different location where no visual archaeological remains exist, and thus participants could not be influenced by them. It was not possible to find a site of similar size as Bar Hill, but we did locate one that was substantially larger than the area participants walked in the first study. If participants covered a larger area, then we could be confident that the physical archaeology was responsible for limiting the exploration. The site was grass covered and 150m x 25m in size. The same content was used, but was rearranged to fit the site (see Figure 8). Digital content was reduced to ensure similar density of content as Study 1.

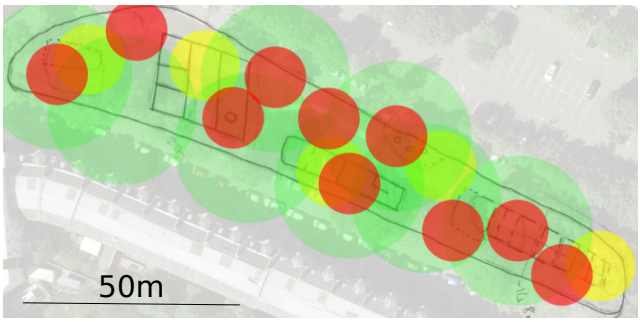

Figure 8. The Study 2 fort, showing Romans (yellow), finds (red), sound effects (green) and their activation zones (circle diameter).

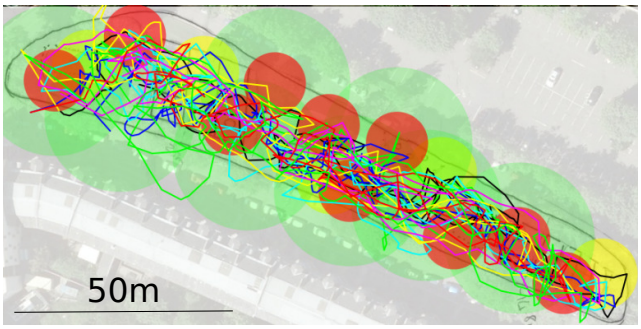

Figure 9. GPS traces for all participants overlaid on the map.

Eight participants (aged 8-14), all members of the Kelvingrove Junior Archaeologists Club, took part. None had taken part in the first study. Participants were divided into two groups of four. Some participants were also accompanied by their parents who had brought them to the club. The procedure was similar to that of the first study. Participants were briefed together indoors on how to use the application before walking a few meters to the evaluation site. At the end of the exploration time (again 15 minutes) participants were taken back indoors for a full group debrief. This covered the topics of the first study, as well as more detailed questions about interaction with Virtual Excavator.

Results

Application logs, videos and the transcription of the debrief sessions were analysed using a framework approach [10]. Initial categories were based on those of Study 1.

Physical Exploration

Figure 9 illustrates the GPS traces for all participants in Study 2. Although the physical space that the fort was contained in was smaller than at Bar Hill, the area covered by participants, excluding the obvious GPS jumps onto the road and other straight line segments, was greater than either condition in Study 1: 2187m^2 vs. 1464m^2 (Study 1 Site Guide) and 1240m^2 (Study 1 Virtual Excavator).

Whilst the lack of physical boundaries allowed users to cover a greater area of the site, participants had to develop different strategies other than walking along the walls as seen in Study 1 in order to systematically explore the site. In the de-

briefing session, with the aid of a paper copy of the map, participants were able to explain the strategies they employed. Related to using the walls as an exploration aid in Study 1, some participants moved from building to building on the visual map. The map displayed on the screen of the mobile device offered participants a substitute for the lack of physical landmarks and it was used to ground their exploration: *"I didn't take my eyes off the screen. I just kept looking at the screen all the time. So that I could see where I was in the map and if I was close to any of the buildings."*. Another commented: *"I kind of tried to get into the little rooms to see if there's anything there."* Others used a more structured approach, traversing up and down the site: *"We tried to go up and down there* (pointing at the map), *didn't we. And we lost our way a wee bit. I think we kept doubling back to see if we'd missed anything because it didn't feel as if we were picking up as much as other people"*.

Whilst the lack of physical archaeological remains freed users to walk over a larger area, there was still evidence that the physical environment guided exploration of the fort. One participant described his exploration of the fort: *"Yes. Well, I started off here* (refers to map) *then I went down to the lake here* (refers to map), *I don't know why, but then I went along -"*. The physical feature of "the lake", which was really a large puddle, guided users' exploration rather than constraining it, as occurred with the physical remains in Study 1.

Interaction with Finds and Romans

As with Study 1, participants were strongly focused on the finds rather than the Romans. As would be expected, since participants walked around more, interactions with finds and Romans were more frequent. Overall there were 70 interactions with Romans and 54 find excavations. Five of the participants rated discovering finds as their favourite part of the experience, the other three rating it as their second favourite part. Only two participants rated interacting with Romans as one of their top three favourite parts. As with the participants of Study 1, when asked what they remembered, participants focused on the finds over the Romans. Whilst collecting finds was an important part of their popularity, *"We did* (double back). *Because we needed to find the Roman coin"*, the physical act of excavation was also cited as a reason: *"I liked how you had to shake it to dig up the find"*. As with Study 1, participants began to understand that the sound effects might indicate the location of an find: *"I got a sort of kitchen noise and then I found two finds when I went towards it. So I think it was when you were getting near to something"*. In addition, this sense of needing to walk to uncover a find extended to participants creating strategies by focusing in and around the buildings to improve their chances: *"I kind of tried to get into the little rooms* (buildings in the fort) *to see if there's anything there"*.

Again, the Romans were less interesting to users. On average a Roman was listened to for only eight seconds, and there were only five occasions where the entire speech was heard. Half of the participants found that the sounds could be confusing and that it was hard to hear the Romans if they mixed with nearby environmental audio: *I didn't like it when they were talking. It had the noise in the background like the leader of the cohort. When he was talking you could hear the army marching, but you couldn't hear his voice.*". Due to the relative physical location of the user to other auditory sources, the relative levels of audio can vary. E.g. standing next to a hammering sound when listening to someone talking. Modifying the soundscape by reducing the volume of other sounds when a Roman is being presented can assist with this. During pilot testing on both study sites we felt this unnecessary. However, for some participants it clearly was a problem. Careful design of the spatialised auditory environment is essential when audio is being used to fulfil so many roles. Nevertheless, this still does not fully explain why users did not engage with the Romans and further work is clearly necessary to further investigate this issue.

Group Interaction

Although the composition of the groups was different between the two studies, we identified many of the same types of group interaction as in Study 1; only the "pack hunting" strategy was not observed. However, the nature of the collaboration was quite different. In Study 1 participants had been explicit and verbal in comparing finds with each other. Whereas, in Study 2 participants were rarely verbal, and comparisons with each other were mostly done by "shoulder surfing" the other person's map to identify what they had found, or indicating to another user the direction where more finds might be found. There was also a difference between the two groups of four users that took part in Study 2. The first group included a brother and sister who were accompanied by their mother, and another participant who was accompanied by his father. Whilst the parents did interact with the children, encouraging and supporting their exploration, there were more interactions between the participants than in the second group of four who had very few. The reasons for this difference between the two groups were the same as identified in Study 1: discovering more finds. One participant noted how he employed the "stalking" strategy from Study 1 to increase his finds: *"I was walking beside those two and I kept trying to hear them find things and I was like - because I wanted to walk over and find the - and dad also helped me"*. Another participant also discussed how she might "trade" finds with someone else: *"I had a couple of things and they... because I had, like, five things and I thought, 'I'm going to get someone to help,' because I found a lot of things. If I didn't have a lot of things, I would have just kept following people"*. Participants in the second group were more competitive, wanting to have more finds than the others: *"Out of everyone else, I wanted to have all the best"*. These participants were also keen to find out how many finds in total could be excavated, and if they had found them all.

Understanding of the Archaeological Site

One area that was the same between both studies was the keenness of participants to show off their finds. This occurred in Study 1 with the older mentors, and in Study 2 with the experimenters, parents and head of the archaeology club who visited half way through the study. This extended to the debriefing, with participants using it as a way of reflecting and discussing with each other their understanding of the site. The female participant from the first group, whose mother was also present, described her favourite part

as being next to the puddle on-site because she found a shoe she had previously seen in a museum. This triggered an exchange over when she had seen the real shoe, similar to participants handling real finds in Study 1. A later exchange involved discussion of a game board that had been found and how the Romans played games. In both studies, participants used activities after their experience to reflect and contextualise. Whilst this shows understanding of the archaeological site can be gained from Virtual Excavator, how this might be accomplished outside of a study where no later activities might be carried out, is unclear.

IMPLICATIONS FOR DESIGN

From both studies we can draw clear guidance for location based experiences for un-stewarded archaeological sites, as well as identify important avenues for future investigation.

Encourage Exploration

The physical space exerted a strong influence over participants in both studies. In Study 2 this was a positive guiding role, but in Study 1, where visual archaeology existed, the effect was to constrain users to that area. This is distinct from prior work [3, 6] where uniformity of the physical environment did not reveal these issues. The "patchy" nature of remains at un-stewarded sites demands that users be supported to explore, and thus understand, the entire site, even those parts where no remains exist. The use of environmental sound as a means to encourage users to move and explore was only partly successful, helping users locate finds but not pulling them to areas with no visual remains, such as the cooking area in Study 1. It is also important that technology supports and encourages exploration in those areas that might not be visually obvious. For example, Facer *et al.* [8] discuss "wicked problems" that do not have a simple or obvious solution. We could require that some finds are discovered before others can be understood. E.g. a mosaic that needs to be reassembled with parts spread across the entire site. On assembly, the mosaic would provide clues to other finds. Alternately, more useful Romans could be moved dynamically, giving the impression they were walking around the site. The user would need to follow, encouraging movement between visual and non-visual archaeology.

Balance Content

Virtual Excavator offered two types of information: Romans and finds. Users immediately embraced the finds and the physicality of their discovery. Romans, although we had made considerable effort and used real actors, received a more neutral acceptance (Study 1) or were dismissed after a few seconds (Study 2). The overriding dominance of one type of information largely drowned out that of the other. Designers should be aware if this is likely to occur, and take steps to improve the usefulness of the "neglected" information. These include incorporating information about finds into the Roman actors. For example, we used finds to guide our Roman persona development (e.g. we took one soldier's name from a name carved on a small barrel). This approach could be taken further, with the Roman discussing the find and where it had been dropped or lost in the fort. Alternately, Romans could be collected in the same way as finds, which might promote their usefulness. In any case, Study 1 indicates that users will listen to the sound for a maximum of around 30 seconds before cutting it off. Our 45-50 second dialogs were clearly too long.

Support Collaboration and Competition

It was clear from both studies that users engaged in collaborative and competitive behaviour. From other studies we know this is not a new concept [16]. However, in the context of un-stewarded archaeological sites, there are wider issues. Firstly, we cannot be sure how large a group of real users would be. This is one reason why we avoided allocating participants to different roles such as with Costabile *et al.* [6]. Visitors might be a child and parents, grandparents or there could be a class of children on a school trip. Support for group behaviour needs to extend to these sizes. Given the infrequency of visitors, collaboration might need to be temporally extended as well, allowing visitors to leave clues and comments that could be accessed by later visitors. A simple way to support variations in size could be to ensure that each find could only be excavated by a maximum of one person during a session. Coupled with the component finds discussed for encouraging exploration, this could allow a balance between competition with others, whilst requiring collaboration to uncover certain finds. However, this would require there to be a reliable network connection between devices. In urban environments we can assume this most of the time, but in rural locations access may be much poorer.

Support Reflection and Understanding

Reflecting upon an experience allows greater learning and understanding to take place [8], and this is something we also observed. During both Study 1 and the debrief of Study 2 there were occasions, post-interaction with the application, where users enhanced their understanding of what they saw and found. The issue with un-stewarded archaeological sites is that these activities were unique to our study: in real use, users making independent visits would not be debriefed after a day out, and the lack of staff or guides make the kind of reflection previously employed in MRE studies [12] impractical. New ways to allow this need to be developed. One option might be to again exploit the natural feeling of discovery exhibited by participants, by providing the location of the museum where the real find is held. Being able to visit and see the find that was virtually excavated may provide the distance and space necessary to allow for reflection.

DISCUSSION AND CONCLUSIONS

Our work over both studies has provided a baseline of the role of augmented audio reality within the context of un-stewarded archaeological sites. They provide a key baseline for us to develop from. We have identified, and in parts solved, key issues when trying to create engaging, interactive experiences at un-stewarded archaeological sites. We have identified that the amount and distribution of physical remains has a significant impact on user's explorations, and that encouragement to explore outwith those remains is a key future challenge. Unlike the issues of audio isolation, identified by *Sotto Voce* [13], we did not find that audio was isolating, but supported significant collaboration amongst users. That sounds were fixed to the environment meant that users in a similar location were listening to similar sounds which

may have assisted in collaborations. For example, the "pack hunting" strategy previously described. This indicates that we may be able to work around some of the issues of unstable or unreliable networking at these sites and incorporate variations of the techniques used by prior work. However, to what extent requires further work.

Our work here has focused on young children as participants. Primarily, this is due to their availability and that they are the groups who would have most issue in understanding the site. However, our goal is to create techniques that work for all users and provide collaborative experiences that bridge the gap between users. Visitors, for example, may be grandparents and children on a day out. How can we create experiences that bridge this? Further studies of Virtual Excavator will be undertaken with other user groups, such as the elderly, to identify in what way our approach needs to change to accommodate such groups. Initial pilots indicate that our current approach works, but may not be ideal given the physical demands of uncovering virtual finds. An additional challenge that we have not addressed, is how to encourage visitors to visit these sites. We have shown that engaging interactive experiences can be provided, but assume visitors will come to the site and have the app already on their devices. This may not be the case. We are therefore exploring how to engage these sites with museums: using visits to the museum to encourage travel to, and exploration of, nearby un-stewarded sites, as well as how to support the reflective element by encouraging visits of the site to extend to museums. In this way we hope to support visitors to engage and discover currently ignored un-stewarded sites.

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