Noname manuscript No.
(will be inserted by the editor)

Performative Technologies for Heritage Site Regeneration

Liam Betsworth · Huw Bowen · Simon Robinson · Matt Jones

Received: date / Accepted: date

Abstract Heritage sites are an important part of understanding our role in history. They have the potential to teach us important lessons, such as where we came from and subsequently, the people it has made us today. As members of a large, heritage-led, regeneration project, we are working with the Hafod-Morfa Copperworks, a heritage site in the Lower Swansea Valley where there is not much to see or hear. The few ruins at the site make it difficult to imagine what the site would have been like back in its heyday.

Our goal at the site is to draw people together, not to view a finished piece of curated heritage, but rather, to start conversations about their memories and the significance of the site to them and to discover what they would like to see at the site in the future. The technology we are producing is about engaging with the local community and stakeholders as groups to provoke discussion. This contrasts with previous uses of mobile guides which only attempt to be tourist aids. In this article, we report on two prototype technologies we have developed to help accomplish this task.

Throughout the article, we discuss how and why designing performative technologies could help encourage people to visit, socialise and communicate within the area. Our early results suggest that expressive performative technologies are good at gaining spectators' attention and encouraging an active engagement between performer and spectator.

Keywords Performance · Heritage · Regeneration · Pico projection · Situated audio

L. Betsworth
Future Interaction Technology Lab, Swansea University
Tel.: +44-1792-602693
E-mail: csliamb@swansea.ac.uk

H. Bowen
History and Classics, Swansea University

S. Robinson & M. Jones
Future Interaction Technology Lab, Swansea University

1 Introduction

When Britain's industrial age went into decline in the early 20th century, many buildings and factories were demolished or, in a few cases, renovated to house new activities. Other industrial sites, however, were simply neglected and ignored. One notable site - which is the subject of this study - was completely abandoned and left exposed to vandals and the elements for over 30 years. This is the Hafod-Morfa Copperworks (see Fig. 1) in the Lower Swansea Valley, located on a $12\frac{1}{2}$-acre site just to the north of the city of Swansea, Wales. By 1890 the Hafod works was the largest copperworks in Europe, and it lay at the heart of a global network of supply. Since the 1830s, ores had been shipped in from not only Cornwall, but also far-away mines in Chile, Cuba, North America, South Australia, and elsewhere, giving rise to the world's first globally integrated heavy industry. The Lower Swansea Valley was one of the most heavily and intensively industrialised parts of the UK, and the sulphurous fumes given off by the smelting works poisoned the landscape and rivers.

Due to the historical significance of this site, a number of organisations led by Swansea University have come together in a multi-partner project known as *Cu @ Swansea*[1], to raise awareness and explore the possibilities of regenerating the site. The outcome of this has meant the beginning of a large, long-term development programme, which is attempting to breathe new life into the site through a careful blend of renovation and regeneration. The primary focus of this project is to make the site a pleasant, usable area for the public, although in a heritage-led way that attempts to preserve the history that is there to be

[1] `http://www.welshcopper.org.uk/en/Cu@Swansea.htm`

Fig. 1 A crumbling building at the Hafod Copperworks (2012)

seen and interpreted. As members of this project, we have begun to explore new and interesting interaction techniques that could be used to help the regeneration of the site. Our initial efforts have focused on preliminary tests off-site, due to early renovations at the Copperworks.

Visitor attractions such as heritage sites have come a long way with technology adoption in recent years. Gone are the days where exhibits and points of interest were merely detailed on a signpost. With today's widespread use of smart phones with internet access, the minimum that one can expect to see at such sites is a collection of QR codes directing visitors to rich web resources such as audio, photo and video. Many visitor attractions (e.g., Kew Gardens [21]) now offer a mobile application that acts as an interactive tour guide. Although these applications work well as mobile guides, there is a potential limitation, however. In general, the kind of interactions that these applications and mobile devices afford are personal. In such attractions where visitors come together, we see a great opportunity for new, collaborative kinds of experiences where users can work together in groups and with different devices [24].

Similar to other heritage sites that have missing buildings and artefacts that are in a state of disrepair, when visiting the Hafod Copperworks, it is impossible to imagine the sheer scale of the industrious activity that went on at the site. When using technology to aid visitors in interpreting a site, it is always possible that the technology itself can become a distraction, or even the focus. At the Hafod Copperworks, we want people to be able to share, have a sociable experience and to open up to experiences that happen at the site – not just those on the device. We imagine the site coming to life and people interacting with the environment. We believe that all of these factors are particularly important to ensure the successful regeneration of the site. As the Hafod Copperworks is currently somewhat of a blank canvas, we would like people's social interactions and experiences to help shape and rebuild the site.

When attempting to develop a system for a more social experience, it makes sense to think of the design and evaluation from a performative perspective. A performative experience is one where the user is the system operator, performer and spectator of their own actions [7]. Key to this performance is the user's perception of the system and their surroundings. Where bystanders are present, they too are classed as spectators to the performance. Although there is no formal definition of what the *most* performative kind of interaction is, we will assume that it is the most expressive one. To make a system *more* expressive, following Reeves et al.'s advice [28], we would need to make the user's manipulations more visible or amplified. In terms of the effect, that too must also be amplified. In theory, the amplified manipulations and effects of an expressive performance should make it more accessible to spectators, although again, perception can play a large role in the effectiveness of this technique [7].

In recent years, there has been a growing trend towards the use of mobile technologies–devices that we use when we are out and about. The fact that we use the majority of our mobile devices in front of others, in focused relation to our surroundings [7], makes the performance metaphor more relevant than ever. The growing number of publications [3, 28, 7] and workshops [32, 13, 44,

40] regarding performative interactions suggest that it is a topic with growing interest in the field of human computer interaction. The work described in this article contributes to research on performative technologies and approaches.

Here, in this article, we report on a number of off-site studies that we have conducted to test the systems before their full deployment in situ. By combining the findings of these studies with those of our heritage-based focus group, we argue that this research provides a solid foundation for considering the suitability of deploying performative technologies in a heritage context.

This article is organised into six sections, bringing together work already published with additional, new significant contributions. Section 2 discusses related work in this area. Section 3 details a prototype performative visual system that makes use of handheld-projection, along with an analysis of its initial exploratory deployment. Section 4 then details a prototype performative audio system that uses situated speakers, along with an in-depth investigation of the system. Section 5 discusses the role of both these systems in the context of performance for regeneration, including discussions and a demonstration with a focus group. Section 6 concludes the article, recapping our research goals and findings and outlining future work.

2 Related Work

The related work on this topic has been divided into three key areas. These are: performance; location-based experiences; and, then location-based experiences specifically tailored to heritage and regeneration.

In Section 2.1, we discuss the notion of performance from both the view of the performer and the spectator. We present an argument for designing more performative experiences and then give multiple examples of existing works that have attempted to design and evaluate performative experiences. Section 2.2 introduces a number of different location-based experiences that make use of spatial audio and projection. Some of these technologies are used indoors and others outdoors. We also attempt to cover a range of technologies that offer the user different levels of control and portability. We conclude the related work with Section 2.3, discussing visitor guides and location-based experiences built solely for heritage and archeological sites.

2.1 Performance

According to Goffman, any interaction that we have with others in our everyday lives, even a one-to-one conversation, can be seen as a performance [10]. We are constantly aware of our appearance to others, conscious of the impression that we are giving. Goffman defines the kinds of interactions where we choose to actively participate and pay attention to a person or group as focused interactions [11]. Unfocused interactions are those where we are aware of each others' presence, but choose not to interact. This is generally how most people behave in public spaces.

In a performance –be it technologically mediated or not– a large factor in the impression that we give others can be derived from the observability of our actions and their subsequent reactions. Reeves et al. developed a taxonomy to classify a performance using the different levels of observability as a spectator [28]. In this taxonomy, a performance or interaction can be categorised into one of four classes. These are: secretive, suspenseful, magical and expressive. Each of these kinds of performances is classified by the observability of both its manipulations and effects, which range from hidden to amplified. In most cases, performative interactions can be thought of as a single class, but Benford et al. [2] demonstrated that a complex interface can successfully cover all four classes in the taxonomy. The relationship between the user, system and spectator in a performance has been discussed in depth by Dalsgaard and Hansen [7]. Here, the term *performing perception* is used to describe how the user is "simultaneously engaged in three actions" - the act of interacting, the act of performing and the act of perceiving. These three acts relate to being "the operator of the system, the performer for people present, and the spectator of the action in her immediate surroundings" respectively.

Returning to the observability of a performance as a spectator [28], as personal devices, many of the interactions that we carry out on our mobile devices could be seen as secretive. While this is desirable for private communications and such, by designing all of our mobile interactions to be secretive, we are missing a potential opportunity to engage with others. In [18], Jones makes an argument for more expressive, extravagant computing. With too many private or secretive mobile interactions, it is easy to see how we may end up cutting ourselves off from the world around us. Perhaps then, as he puts it, we should strive for more "extravagant, expressive, place-based computing," where we attempt to make use of more amplified manipulations and effects. With respect to mobile devices, we believe that gestures are a good example of an amplified manipulation. The highly visible and expressive nature of gestures allow them to become a much more amplified manipulation than a button press on a mobile device screen. The acceptability of gesturing in public is a topic that has been covered in depth by Rico et al. [31]. Further work has also touched on the social acceptability of multimodal performance in public spaces [43].

Much of the literature regarding the design and evaluation of artistic installations focuses on the theme of performance. The *humanaquarium* [39] is one such project, where the designers themselves became performers, improvising music from an acrylic box. Bystanders were able to control the performance by making contact with the touch sensitive front. Over the course of a year, the designers were able to "gradually re-imagine content and interaction strategies in response to a deepening understanding of the design space gained through performing the work in public" [39]. The design of ubiquitous, performative experiences is a topic that has been discussed in depth by Jacucci et al. in [16].

2.2 Location-based Experiences

When visiting new and unfamiliar areas, electronic mobile tour guides have become a popular way to navigate and access relevant information about one's surroundings. Kenteris et al. carried out a detailed survey of electronic mobile guides [20], attempting to evaluate them and extract important design principles. Although many of these guides are now outdated by multipurpose location based services available on smartphones, there is a recurring theme with these kinds of applications - they rely on constant attention to the technology, consequently diverting attention from ones surroundings. Before mobile internet-connected devices and such location based services, we used to look around and explore; now, as argued by Jones [18], perhaps the dangers of such systems are that we end up walking into "public places we no longer connect with—where people pass each other, digitally divided." Mobile devices such as smartphones now have a whole array of useful sensors and modalities that we are able to exploit, giving us the opportunity to break away from the trend of mobile screen-based electronic guides. In an attempt to draw people away from the mobile screen, we have looked at developing publicly visible and audible content using projectors and speakers. The following research projects are a few examples of those that attempt to offer the user a more public and collaborative experience using such audio and visual modalities.

In recent years, the projector has emerged as a piece of apparatus that is used fairly often, both indoors and outdoors for museums, art installations and exhibits [23,5,37,22,36,15]. Bert Bongers was one of the first to realise the potential of taking a projector outside of its intended context [5]. Before the introduction of pico projectors, Bongers took to the streets at night with a full sized projector to project gateways to alternate realities. Over time, situated projections have become more interactive, with certain examples allowing users to control the content that is projected by external means [37,22]. In L.A.S.E.R. Tag [22], a user is able to use a laser pointer as a paintbrush. The projections are aimed at large outdoor objects, giving the user a canvas to paint over the real world. Sauter developed an intrusive but playful artwork named Light Attack [36], where a white silhouette of a person was projected onto the walls and sidewalks of streets from a moving car. A further example of situated, but moving projection is demonstrated in [15], where projections are dynamically generated and displayed on the banks of a river from a riverboat.

Since the introduction of pico projectors, although there has been interest in their uses in public space, there has been little research regarding their usage with mobile guides - in particular, where a person is able to explore and learn about the place that they are in. Pathlight [42] is a mobile guide designed for a museum. Its main purpose is to give information about exhibits, but it also doubles up as a navigation guide within the museum, directing the user to different exhibits using projected arrows.

In terms of audio, there are some notable examples of projects attempting to change the audio guide from a linear, button activated spoken information source into a rich, spatial audio display that makes use of contextual sounds.

The roaring navigator [38] is a mobile audio guide for a zoo that plays the sounds of animals that are in front of the user. Users may then navigate towards these animals by listening to the audio stream, with sounds panning to either the left or right ear depending on the location of the animal enclosure relative to the user. Moving away from headphones and into the public audio domain, Ambient Wood [33] was a research project where Rogers et al. experimented with new forms of digital augmentation for learning outdoors. One of the technologies they introduced was wireless speakers that play environmental sounds. Our prototypes take inspiration from these projects, attempting to create more exciting, public, sociable experiences.

2.3 Heritage and Regeneration

In an attempt to spark interest and encourage visitors to heritage sites, a number of research projects have worked on developing location-based experiences for such sites. An example of one of the first experiences such as this that appears in the literature is Archeoguide [41], an augmented-reality system that could render missing structures at heritage sites on a display for the user.

In terms of audio, there are multiple examples of audio guides for heritage sites that require the use of headphones. To the castle! [8] attempted to compare a people-led guided tour with an audio, technology-led guided tour. The technology-led tour worked by triggering audio clips as users walked through a specific GPS point. Although the audio was location-based, it was not spatial once triggered. The researchers evaluated each approach by observing participants, asking them to complete a questionnaire after each walk and inviting selected participants to a debriefing session. A key finding was that participants thought the 5-7 minute audio clips were too long and too dry, with many participants not listening to entire audio clips.

Some more adventurous heritage audio guides have made use of spatial audio. One of the first examples that used spatial audio was *Riot! 1831* [29,30]. In this project, Reid et al. attempted to surround the users of the system with the sound of a riot. The user was able to hear different pre-recorded sounds by walking to different areas close-by. Each of these sounds was carefully mapped over the physical environment so that it related to that particular place. Virtual Excavator [26] –another example of a spatial audio guide– was a recent attempt at understanding "how visits to un-stewarded historical sites can be augmented with multimodal interaction to create more engaging experiences." At the Hafod-Morfa Copperworks, we find ourselves in a similar situation to this particular project, with no staff or information available on site. Through the use of three-dimensional audio using headphones and a map on a phone screen, children in each of the two studies were encouraged to explore the site and uncover past findings. Upon making a discovery, users had to shake the device to dig up the item. Because audio was triggered by the user's location, the researchers found that users who stood close to each other did not actually find the audio isolating - they were all receiving the same content at a similar

time. McGookin et al. also found that very often, participants were not drawn towards the contextual spatial audio to make findings as the designers had originally intended, but participants tended to stay around remaining visible physical structures. Similarly in this system, users again complained of long audio clips, but this time with much shorter spoken audio clips of 40-45 seconds in length. Although there are multiple examples of audio guides where participants have argued that the audio recordings were too long [8,26], one audio walk that stands in juxtaposition to these views is Janet Cardiff's 'Her Long Black Hair' [6]. Cardiff's audio recordings were 46 minutes long and again contained historical information, yet users did not complain about the length. For this reason, we conclude that audio length in itself is most likely not the problem. A number of factors are likely to play a part in the overall listenability of an audio guide. In our audio prototypes, we attempt to use short and useful audio clips to improve listenability.

Artido et al. report on the design and evaluation of a system named *Explore!* [1], a system to help children explore sites of cultural interest. Each group of children were given a mobile device, a map and a backpack containing speakers. On the mobile device were hints for completing each mission and visual, three-dimensional reconstructions of historical structures and places at the site. In this research, a special emphasis was placed on the speakers in backpacks, playing contextual sounds depending on the location of the group on site. This approach contrasts with our audio prototype (see Section 4.2), as the speakers in our system are not carried around by users and they are much louder, audible by much larger numbers of people than a single, small group.

3 Performative Projection

The Hafod Copperworks was once alive with molten metal, steam, rivers and smoke, but it now lays bare, with no such visual activity or indicator of what all this may have looked like in the past. The system that we introduce in this section is our attempt at visually enhancing a user's surroundings in a performative manner. As the Hafod Copperworks is currently inaccessible to the public, we had to find a suitable alternative location to conduct this research. We decided upon carrying out this research at the National Botanic Garden of Wales. As an interesting visitor attraction with thriving visitor numbers, it was an appealing location to situate such a system. The following sections describe the design of our performative pico projection system and our evaluation at the Gardens.

3.1 Background

The availability of mobile internet and realtime geolocation is increasingly allowing the information we seek to be linked in some way to the places we visit. Many of the mainstream location-based information services to date

have focused on delivering images, multimedia or text in situ, direct from the internet to a mobile client.

Of these services, there are multiple augmented reality lens applications that make use of a camera, overlaying digital content on a realtime physical world image (e.g., see layar.com). However, while these systems can augment camera images with digital content, the user still has to hold their device in front of the real object – a digital divider between them and the physical world. In place-based magic lens applications, Morrison et al. [27] remark that there is a constant need to reference the physical, yet we argue that when in use, the technology element will always be fairly visible and in the way of the physical.

By using pico projection, we can take this type of AR lens application one step further. By projecting into the environment rather than displaying on a screen, both the limitations of sharing via a small screen and the digital divide presented by the technology visibility are compensated for. Instead of manipulating an image recreated on a device screen, we can now project onto the real world itself. Full-size projectors have been used on many occasions to augment buildings as part of a multimedia performance, using 3D video mapping to make the buildings appear to come to life (e.g. see nuformer.com). With pico projectors we can create a similar display while mobile, but rather than simply informing the user of relevant digital information, we can allow them to become part of the performance itself.

In this section, we report on a prototype system to display pico projected images and animations. By using a handheld projector to view digital content, instead of the typical touch screen on a modern mobile device, we aim to allow for more expressive mobile computing experiences, with performance and collaboration in mind. The novelty of this work lies with the use of pico projection to augment exhibits at a visitor attraction. In particular, there was a large emphasis on the user being able to control the placement of the projections in a free-form way, positioning projections using a red dot, preventing the need for a sophisticated tracking system. While some of the findings have been seen in prior works, the performative perspective of this research sheds new light on the possibilities.

Our approach contrasts text projection onto objects [19], as we do not project text information into the envionrment, but visual animations that attempt to overlay and bring the environment to life. The majority of the content in this section is based on work presented by Betsworth et al. [4].

3.2 Prototype

We developed a mobile prototype to demonstrate performative, place-based projection. Since we wanted to test the system with real visitors at a local attraction, we worked with the curators of the National Botanic Garden of Wales, carefully crafting and tailoring the types of performative projection specifically to the context of their visitor attractions. One of the key reasons for working with this attraction was their previous interest in being early adopters

of emerging technologies. For example, the gardens (both outdoor sections and displays in the large indoor glasshouse) are viewable on Google Street View [12], allowing visitors an online 3D tour of the attraction before visiting. Our system reuses QR codes and some curated content from a previous project at the National Botanic Garden of Wales (similar to [34]). We use QR codes for indoor location awareness and as a visual indicator to show users that they can interact with that exhibit.

For this research, our main aim in using a pico projector is not as extra screen space, but specifically to allow a visitor to augment the real plants and objects with digital content, acting out or performing actions with the elements they project. In the context of this paper, we define performance as manipulating the projections to achieve effects with the projected content. Where spectators are present, the moving and positioning of the projector and the effect can create an illusion of AR.

Rather than previous lens-based approaches, however, the augmentation is projected directly onto the physical elements to which it refers. Our system uses an iPod touch attached to a pico projector (see Fig. 2). The iPod is used to scan QR codes situated next to eight exhibits around the gardens' visitor centre. After scanning, an image and sentence of context about the exhibit are shown onscreen, along with a prompt to focus a projected target on the object. The user presses a button when ready, and imagery or animation is then projected. As the prototype was built for use at this specific attraction, the imagery used is of insects, animals or environmental factors that are related to the plants and other displays at the botanic gardens. Figure 3 shows several such examples, where the projection appears next to or on top of the related artefact. Apart from the initial QR scan, the system does not implement any additional tracking. This allows users of the system to project freely onto objects in an attempt to promote performative and playful behaviour. For this prototype, content and QR codes are stored and recognised locally, as the device is designed specifically to augment this particular attraction. For use with a wider set of attractions, we imagine an online repository of content paired with displays in other visitor centres.

3.2.1 Informative, screen-based system

We also built a second, alternative mode into the system, allowing us to compare traditional screen-based location information with the projected content approach. After recognising the QR code and showing the same initial content on-screen as in the performative system (i.e., a sentence of context and an image), upon pressing a button it then displays a page of textual information about the object, instead of a projection (see Fig. 2).

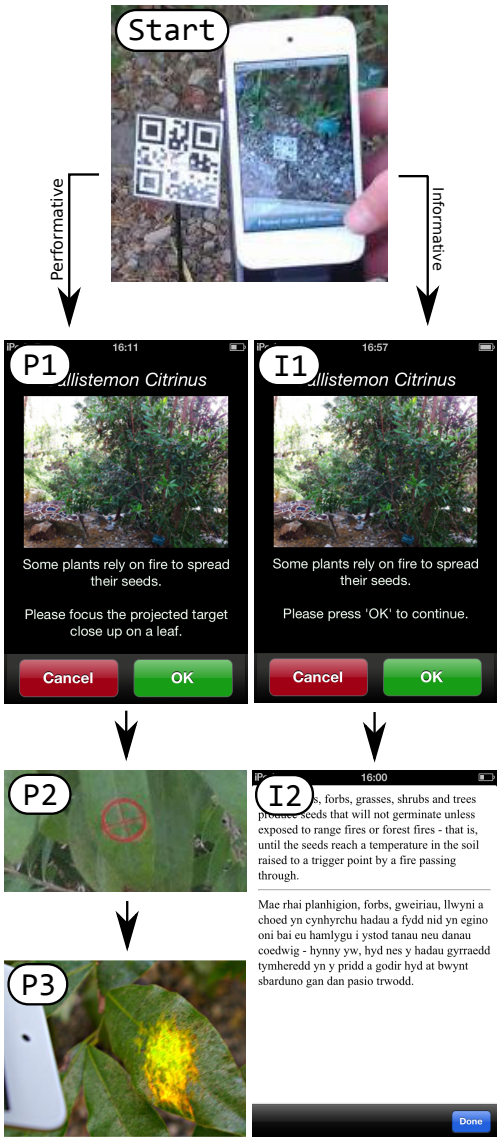

Fig. 2 Using both prototype systems: scan QR code with iPod touch (Start) *Performative:* prepare (P1 & P2; confirm and point target) and project (P3; a fire) or, at right, *Informative:* confirm scan (I1) and display text (I2).

3.3 Initial Exploratory Deployment

We conducted a study over six days at the National Botanic Garden of Wales. The aim was to test both systems with real visitors in situ. We had two research questions:

Fig. 3 Projecting images and animations in *performative* mode. Clockwise from top left, projections show: a leaf on fire; a sunbird flying to a plant; raindrops falling on a leaf; and, a witchetty grub on a tree trunk.

RQ1: How do perceived learning and enjoyment through performance with projections compare to perceived learning and enjoyment with text-based information?

RQ2: How does the performative aspect of the projector system affect involvement or interest from non-participant visitors when compared to the informative system?

3.3.1 Participants

Twenty groups of participants were recruited as they entered the building. Ten groups used the informative system and ten used the performative system. A total of 58 participants took part, with 34 people using the informative and 24 using the performative system. Participants' ages ranged from 3–80, with 29M (Male), 29F (Female) overall, and similar gender distribution between systems. The average group size was 3 participants.

3.3.2 Measures

To gather users' opinions of the system, a short survey was built into the prototype. After scanning a QR code and either projecting or reading the related content, the prototype prompted the group to give feedback. Groups were instructed to give feedback collectively. The survey questions asked:

1. *How many other visitors stopped to look at what you were doing?*

2. *Rate your enjoyment of this particular QR code experience.*
3. *Rate the value of this particular QR code experience as a learning resource.*
4. *How has your understanding been affected by this QR experience?*

Questions 2 and 3 allowed participants to select a rating from 1 (low) to 5 (high). Q4 allowed a selection from 'decreased,' 'unaffected,' and 'increased.' In addition to the survey, participants answered a short semi-structured interview at the start and end of each session. For one of the six days, two additional researchers observed groups' behaviours from a distance while they used the prototype, being careful to avoid intruding on the experience. In total four groups (13 visitors) were observed, with three using the performative and one using the informative system. In addition, during that day, many visitors who were not participating in the study were also observed.

3.3.3 Procedure

After groups agreed to participate, a short training session was conducted to demonstrate usage of the system to the group. The group was then given the prototype (in either performative or informative mode), and an information sheet in case they needed further guidance. This sheet also incorporated a map showing the approximate location of eight QR codes to scan (see Fig. 4). Because the study was conducted in such a brightly lit area, the location of each of these codes was carefully selected so that projections would have the best visibility possible. These areas were shaded and darker than the rest of the glasshouse.

After receiving these instructions, the group then left the researcher, finding and scanning each separate code and completing the five survey questions after viewing the content associated with each display. Discreet observations were made of participants during some study sessions. At the end of each session, the group were debriefed in a short post-study interview, thanked for participating and given a gift voucher.

3.3.4 Results

Firstly, we will consider the data gathered by the mobile application after each exhibit (see Fig. 5). For Q1, the average numbers of non-participant visitors that were reported were 1.39 for the informative system (sd: 1.66) and 1.88 for the performative system (sd: 2.33). There is an overall significant difference in participants' rating of whether their understanding of an exhibit was affected (Q4), with the informative system seen to be more beneficial in that respect ($p < 0.002$; Mann-Whitney). Turning to the ratings of enjoyment (Q2) and perceived learning (Q3), there was no significant difference between systems.

In the post-study interview, all participants indicated that they had noticed interest from other non-participant visitors around them. A common sentiment was captured by one participant, who said: "if people were around

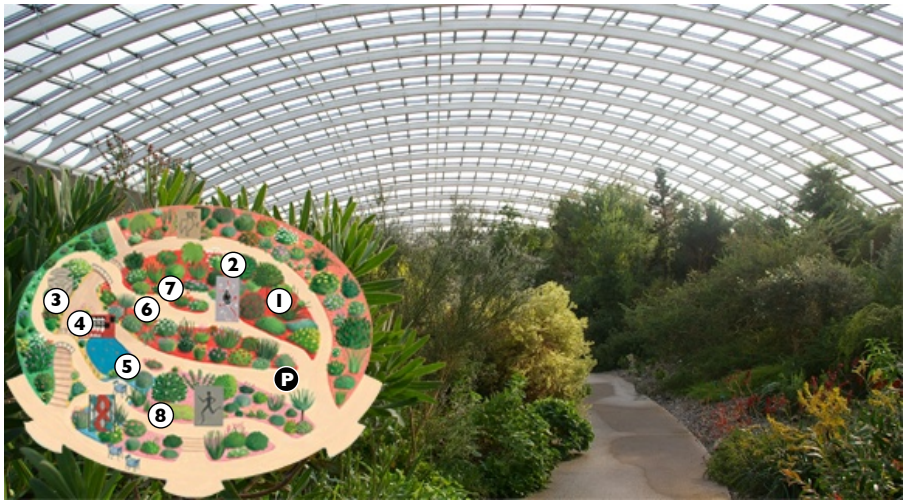

Fig. 4 *Top:* the large glasshouse in which the study took place. *Bottom:* the garden map with exhibit locations 1–8 indicated.

they looked." In some instances, other visitors were curious enough to ask participants what they were doing. Three groups using the performative system reported that they demonstrated the system and engaged with non-participant visitors. One of these said that their performance involved 13 visitors who became interested in what was happening.

Participants often commented that the system they used added interest to their visit, with one participant claiming that the performative system gave "an extra dimension." Some of the groups with children (using either of the systems) noted the enjoyment in seeking out and scanning the QR codes themselves. One participant using the informative system explained this, but noted: "the children love to find the codes and scan them but they're not interested in reading any of them." Several participants commented that the brightness of the projector was sometimes an issue.

Observations Considering first the group observed using the informative system (four adults; one child) – in general this group gathered closely around the system after scanning each QR code. No single individual in this group took control of the prototype; instead, participants took it in turns to scan each QR code. In some cases one participant read aloud to the rest of the group; for other exhibits individuals read to themselves instead, huddled tightly around the device. While other visitors were aware that the group were doing something unusual, they were not seen to experience the information the group was reading.

With the performative system, where three groups were observed, there was evidence that projection encouraged participation beyond the device itself. Participants were not gathered around the device, but were seen to be focused

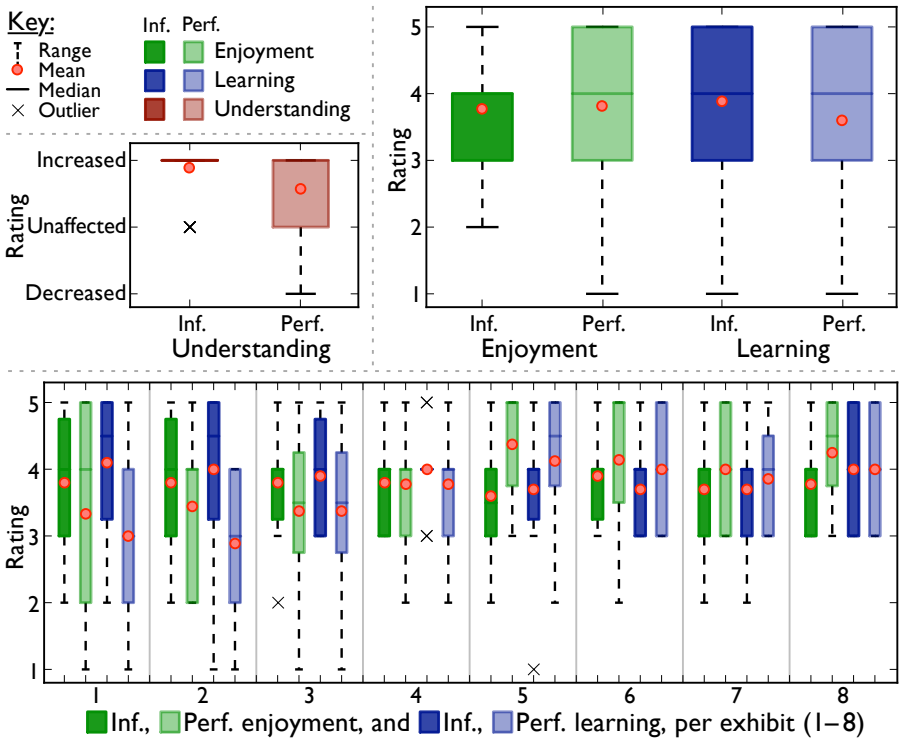

Fig. 5 Box plots of survey results (Q1, Q2, Q3) for both systems. Top: overall results between systems: understanding is significantly increased when using the informative system, but there is no evidence of an effect on enjoyment or learning. Bottom: individual results for enjoyment and learning separated into exhibits 1–8.

on the projections rather than the prototype. In one group (two adults; two children), an adult held the device and let the children direct his hand, pointing the projections at plants while visitors stood by and watched.

3.3.5 Discussion

The higher rating given to the informative system in terms of "understanding" is not surprising given that the system provided detailed textual content for each exhibit, in contrast to the performative system's images and animations. We might have expected a higher rating for perceived "learning" in the informative version for similar reasons; and, conversely, a higher rating for "enjoyment" for the performative. However, no significant effect was apparent. For this reason, then, we may speculate that both types of system provide benefits in these respects – allowing for both informative and performative modes in future designs would seem a sensible approach.

Clearly image quality, particularly brightness, impacts on the efficacy of projection. Visibility seems to have played a part in participants' opinion of the performative prototype as a learning resource. No significant difference was

found in the numbers of people reported as stopping to watch by participants using both systems. However, post-study interviews and group observations suggest that bystanders had a more active engagement with the performative prototype.

4 *Surround You*: An Audio-Gestured Interface

Turning now from group viewing of content to collective listing of audio content. The Hafod Copperworks was once alive with sounds. With the crackling of fired up furnaces, the hammering of copper sheets and the constant sound of boats delivering and exporting goods, it would have been a fairly noisy place to be. When standing at the site now, apart from the neighbouring main roads, the site lays silent. The system that we introduce in this section is our attempt at aurally enhancing a user's surroundings in a performative manner. Again, as the Hafod Copperworks was not open for public access at the time of conducting this research, we had to look to conduct our research elsewhere. To successfully evaluate the systems we had built, we required a busy public place with a good network infrastructure. After careful thought, the Swansea University campus appeared to be a suitable location to test these systems. The following sections describe the design and evaluation of a set of performative spatial audio guides.

4.1 Background

In outdoor applications, site-specific audio guides are usually developed for use with headphones [6,35]. Such audio experiences attempt to immerse the user in their current environment, providing them with useful and relevant audio information to interpret. Although these kinds of experiences are now fairly common, there are multiple limitations that leave a desire for a better solution. The first limitation is that headphone audio guides of this kind can sometimes feel synthetic. Instead of augmenting the user's environment with sounds, a new environment is being created within the user's headphones. Additionally, when spatial audio is used with headphones, it can be difficult to distinguish between what is in front of, and what is behind the user.

In terms of a group experience, headphones can be rather isolating. There are examples where researchers have tried to synchronise playback between multiple users headphones in a museum setting [14], but this solution still does not give users the ability to communicate with each other during the experience. While isolating a user may be desirable in some cases, it makes it difficult for the user to socialise and communicate with others that are around them. Communication can be a helpful way of making sense of and interpreting exhibits and points of interest at visitor attractions. Fosh et al. attempted to overcome this limitation [9], by purposely asking users to remove their headphones after receiving information. This allowed them to reflect on what they had just heard.

Returning to the topic of realistic sounding spatial audio, there are other technologies that better deal with this task. Besides using headphones, we can use speakers. A popular spatial audio example of using speakers for spatial audio are 5.1 and 7.1 surround sound. As the names suggest, the 5.1 and 7.1 surround sound technologies can utilise 5 and 7 audio channels respectively, excluding a subwoofer. Surround sound can produce very convincing and realistic spatial audio, but this technique again has limitations - one of which is the limited number of audio channels available. Another limitation of surround sound is that the user is required to remain stationary in the middle of the speakers.

When considering the kinds of selection techniques often used for mobile guides, one of the current limitations to a number entry mobile audio guide is that user's need to first discover the numbers before entering them. If a user does not see a particular number, they miss receiving that piece of information. With our pointing technique mentioned in Section 4.2, if a user walks past a sound point and points at it passively, they still receive the information. Another advantage of our pointing technique is that we do not need to predetermine which number effects each sound point. Once a sound point is set up and knows its location, it can even become mobile and move around, as long as it has GPS capabilities to update its location.

Our goal here was to develop and evaluate an expressive system where m users could move around freely, take control and collaboratively experience n loudspeakers with independent audio streams. In the following sections we present *Surround You*, a public audio interface activated through user gestures.

4.2 Prototype Design

Surround You is a system that attempts to look at spatial audio in a new way. There are three main components to the system, two of which are clients and one of which is the main web server that handles all requests and carries out all of the computational work. The first client is the mobile application that the user sees and uses. This is the controller that is used to actuate each sound point. The second kind of client is the individual sound points. For our experiments, we used netbooks as clients. To each of these sound points, we connected a portable battery powered loudspeaker so that the sound would be audible from a distance (see Fig. 6). A web server was then used to handle communication across client devices.

The main difference between *Surround You* and other embedded speaker systems is that the user has complete control of the output using a mobile device. Also, it is developed in such a way that n speakers may be connected to the system, working as independent audio streams and m users may also connect to the system with the ability to control any of these audio streams simultaneously.

Fig. 6 A sound point - a netbook connected to a battery powered loudspeaker.

4.2.1 Interaction

When designing *Surround You*, we decided that the user manipulations should be amplified and that the effects should also be amplified. This way, in terms of the performance from a spectator's perspective [28], the interaction would be an expressive one. By making an expressive interaction, we hoped that this would be the most engaging experience for bystanders and would encourage them to become involved in the experience.

To activate a sound point, the user must point the mobile device in the direction of a sound point. To compensate for GPS inaccuracies and the relatively small size of the electronic sound point equipment, each sound point is programmed to think that it takes up much more physical space than it actually does. For example, if one of these sound points were to be placed inside an old building at a heritage site, we would assign the diameter of the building to the sound point. If the user then pointed at any point of that building, the sound point would activate and begin playing.

In *Surround You*, each speaker is pre-programmed with its location, making it location-aware. The smartphones we used were GPS enabled, allowing continual calculation of the bearing from the user to the sound point, which would be considered as the valid selection bearing to 1°. Previous research shows that a valid selection range should be at least 20° to achieve 90% accuracy [25]. The web server actively checks the location and orientation of every user in the system, calculating valid playing ranges and using this information to determine whether any of the sound points are currently being pointed at.

When a user interacts with a sound point by pointing the device, we use a tuning-in and tuning-out metaphor. When the user points directly at a sound point, the sound point is at maximum amplitude. The further away the user

points from the centre of the sound point, the more the amplitude decreases. It does this until the user is no longer pointing at the sound point, at which point the amplitude level returns to zero. We used this metaphor so that the audio would gradually fade in and not startle spectators or those standing close to the loudspeakers. In the current implementation of *Surround You*, if more than one user points at the same sound point, the loudspeaker takes the mean amplitude and plays at that volume. The framework is built in such a way that we can quickly and easily change the effect that multiple pointing users have on the system. Possible effects that multiple users have could include increased amplitude or access to different audio streams that are not available to single users.

4.2.2 Control Systems

In comparison to *Surround You*, a standard style audio guide system would use headphones instead of loudspeakers and would require the user to enter a unique number at each of the sound points using a number pad. As a control system, we recreated this standard style audio guide to see how our system fared against existing, conventional audio guide style systems to gain information from surroundings. In terms of manipulations and effects, both are more hidden in this interaction, creating a secretive experience [28] from the point of view of the spectator.

To select a sound point using the number entry manipulation, a user must enter the unique number assigned to that sound point. With the addition of headphones, the loudspeaker feedback is substituted for headphone feedback that only the user can hear.

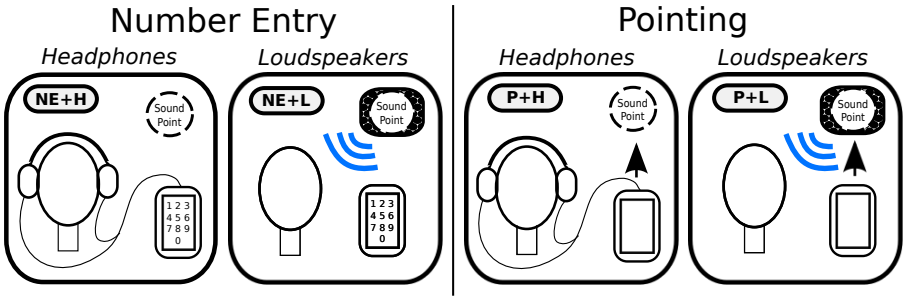

Fig. 7 The four different interaction techniques used for evaluation. From left to right: Secretive (NE+H : *Number Entry & Headphones*), Magical (NE+L : *Number Entry & Loudspeakers*), Suspenseful (P+H : *Pointing & Headphones*) & Expressive (P+L : *Pointing & Loudspeakers*)

Two further systems were created with variations of the different manipulations and effects mentioned. The first of these systems uses the pointing manipulation and gives feedback to the user through the headphones, creating

a suspenseful experience [28]. Our last variation uses the number entry manipulation and the effect is heard through the loudspeakers positioned in the environment, providing a magical experience [28] for the spectator. The four systems can be seen in Figure 7.

4.3 Study

We conducted a study over eight days on the grounds of Swansea University, Wales. During exploratory testing, we discovered that the behaviour of both performer and spectator were interesting, so our study focused on interpreting the behaviour of both participants and bystanders. As we did not question spectators in this study, particular emphasis was placed on finding out the performers enjoyment, comfort and the perceived effect of their performance on bystanders between systems.

4.3.1 Participants

From informal observations, we understand that many of the current visitors who pass nearby the Hafod-Morfa Copperworks are individuals going for a walk, cycle or run, sometimes with pets. Engaging these kinds of visitors is important, as it encourages someone who would usually pass-by to stop, engage with and appreciate the area that they are in. For this reason, participants in this study took part as individuals.

For this study, all participants who were recruited were affiliated with Swansea University. A total of 16 participants (11M, 5F, 18-50 years) took part in the study. This included 2 members of staff and 14 students (6 postgraduates and 8 undergraduates). All participants except one had used a smartphone before, with 13 of the 16 participants owning one. All 16 participants reported having no hearing difficulties prior to taking part in the study.

Before each study session, participants were also asked a set of questions regarding any group activities they regularly partake in (i.e. Team sports, singing, dancing, lecturing etc.) and whether they saw themselves as an introvert, extrovert or ambivert. A short dictionary definition was given to users to help make their choice of personality trait. These questions were asked so that we could gain a brief understanding of how used to performing our participants were. Upon self assessment, 4 participants claimed to be introverts, 1 extrovert and 10 ambiverts. There was one participant who did not wish to answer this question. In terms of group activities, 6 participants reported not partaking in any regular group activities, with the remaining 10 taking part in one or more regular group activities. By observing this data, we concluded that the majority of participants were fairly comfortable performing in front of others, with the remaining $\frac{1}{4}$ of participants having little experience of performing around others.

4.3.2 Procedure

The study was spread over 8 days, with each session lasting for around 30-45 minutes. For most of these days the weather was relatively cold, cloudy and windy. There was only one study session where it began to rain lightly, but the participant decided to carry on with the study. Although the Swansea University campus is not a visitor attraction as such, it was again chosen for the main study as it is a busy public location that provided a good network infrastructure upon which to operate our systems.

When each participant arrived outside at the study location, they were ask to read and agree to the ethically approved research consent form and were given a demographic questionnaire to complete. After completing the short questionnaire, the participant was given a short briefing regarding the capabilities of system, including the different selection (number entry & pointing) and feedback (headphones & loudspeaker) techniques. The participant was also shown the physical location of the four sound points used in the study.

A within-subjects design was used, where each participant was required to use all four of the different systems (see Fig. 7). The order systems were used in was counterbalanced to reduce the effects of presentation order on results. For each condition, the participant was first given instructions as how to use the prototype. For the pointing selection, participants were told that all they were required to do was point at the individual sound points to activate them. For the number entry selection, participants were told that they were required to visit the number displayed at each sound point and enter it into the mobile device. To avoid participants learning the numbers for each sound point and not having the visit them again, two random double digit numbers were displayed on each of the sound points. Each sound point in our experiment consisted of a numbered label and a netbook with a portable speaker (see Fig. 8).

Once participants had been introduced to the first interaction technique, they were asked to explore the area for 2-4 minutes, returning to the researcher once they had activated and listened to all four sound points. During this time,

Fig. 8 *Left:* A participant pointing at a sound point. *Right:* A close up of the sound point - a portable speaker and netbook protected by a waterproof cover. Also, a numbered label for the number entry systems.

the researcher took notes of participant and bystander behaviour. When participants returned to the researcher, they were then given a system with the same manipulation technique (pointing or number entry), but now with either headphones or loudspeaker (depending on which one had not been used). As before, participants were asked to explore the four sound points for a further 2-4 minutes. After using this second system, participants returned to the researcher and were asked to answer some comparative questions regarding the two systems in a questionnaire.

Participants were then asked to repeat the experiment, but using the new input technique (pointing or number entry) with the two different outputs again (headphones & loudspeakers). Once participants had used all four systems and answered the same comparative questionnaire again, participants were then interviewed with questions regarding their entire experience. Participants were thanked for taking part and given a voucher once they had completed the post-study interview.

4.3.3 Data Collection

Data was collected in the form of a pre-study demographic questionnaire, two mid-study questionnaires given to the participant after using both variants of each input system (number entry & pointing), informal observations and a post-study interview.

The pre-study demographic questionnaire focused on gaining background information from a participant such as their experience of mobile phone use, whether they have a hearing impairment, whether they see themselves as an introvert, extrovert or ambivert and if they regularly partake in group activities. These last questions were asked to gain a sense of the personalities of our participants, and whether they were used to performing. The two questionnaires given to participants during the study, required participants to rate their enjoyment and comfort level on a 7-point Likert scale after using each set of systems. One questionnaire was given to the user after using the first two systems with the same selection method (e.g., pointing). The same questionnaire was then given when the user had used the final two systems with the other selection technique (e.g., number entry). At the end of both of these mid-study questionnaires, the participant was asked by the researcher, "What did you think of these two systems?" This question was deliberately left open and allowed participants to compare the systems or give an account of their experience however they pleased. During the study, informal observations were made of both participant and bystander behaviour. In terms of participants, observations of general behaviour when using each system were recorded in note form, along with any incidents that the researcher deemed interesting. For bystander observations, the number of people in the local vicinity was recorded, along with the number of those that stopped to look or reacted to the system in any way. In some cases, detailed accounts of bystander behaviour was also recorded. The post-study interview gave participants an opportunity to reflect on their entire experience.

4.3.4 Results

The following section includes the results from the study, including the two questionnaires given to the participant after each interaction technique, the post-study interview and observations made of participants and spectators during each study session.

Questionnaire Between Interaction Techniques. Participants were asked about their comfort and enjoyment levels when using each of the interaction techniques (see Table 1).

	Number Entry		Pointing	
	Headphones	Loudspeakers	Headphones	Loudspeakers
Comfort (1-7)	6.44 (sd: 0.70)	5.31 (sd: 1.31)	5.69 (sd: 1.26)	4.44 (sd: 1.32)
Enjoyment (1-7)	5.81 (sd: 1.01)	5.63 (sd: 0.85)	5.38 (sd: 1.05)	4.56 (sd: 1.27)

Table 1 Average score for *comfort* and *enjoyment* level for each system (1-7 Likert-like scale; 7 being high).

Pointing and loudspeakers was rated lower than all other interaction types for enjoyment, showing statistical significance against each of the interaction techniques ($p < 0.05$; Wilcoxon signed-rank test). It was also rated as the most uncomfortable, which also showed to be statistically significant against all other interaction techniques ($p < 0.05$; Wilcoxon signed-rank test). Although number entry and headphones was ranked both the most comfortable and the most enjoyable interaction technique, it did not register significantly higher than all of the others. A few participants mentioned that they were more comfortable with using loudspeakers the second time around. As well as the increased control and accuracy of number entry over pointing, some participants also mentioned that they liked the idea of being able to activate a sound point and walk away.

Post-Study Interview. Most participants preferred number entry as a selection technique as opposed to pointing. Participants that chose number entry said that they did so because it worked well and gave them greater control over what was playing. The general consensus among all participants was that pointing was convenient and fun, but again number entry gave more control. Regardless of selection techniques, most participants preferred using headphones as they provided a more personal and less invasive experience, along with the ability to manually control the mobile device volume. Participants that preferred the loudspeakers did so because it was easier to differentiate between audio streams, and they liked the idea of spectators being able to link their pointing gesture to the loudspeaker output.

The vast majority of participants decided that the number entry and headphones interaction offered the most solitary experience. When asked to comment on their views on a solitary experience in this context, participants'

replies were universally positive, with one participant saying, "I was more comfortable, wasn't worried about others and could concentrate on the info." One or more of these individual aspects were mentioned by most participants. When asked about number entry and headphones as individual factors, the view of most was encapsulated by a single participant who said, "people didn't seem to take much notice, it's just normal behaviour." At the other end of the spectrum, most participants thought that the pointing and loudspeaker interaction offered the most sociable experience, with one participant explaining, "they can see the interaction and listen." Participants commented that "some [spectators] were looking for where sound was coming from" and "I think someone stopped their conversation to look and see what was going on." A few participants however, raised concern with the loudspeaker feedback, saying, "the speakers got people's attention, but it depends on the context if it's ok" and "if they want to listen then fine. Otherwise, not so much." The majority of participants did not notice a change in spectator behaviour when pointing, although some participants said that "a couple of people noticed" and "some gave strange looks."

When asked, five people said that they had purposely tried to affect the actions of others or gain reactions from spectators. Of these five, some tried harder than others, claiming that they purposely tried to scare people that were walking by. An example of this was when one participant said, "towards the end, I waited until a guy was in front of it [the speaker]. It didn't scare him, but he jumped a bit." These 5 participants were all seen to be playing around with spectators, trying to make them look for where the sounds were coming from. The other 11 participants claimed that they tried to be as inconspicuous as possible. One participant said, "I tried to stop the sounds as soon as possible. I Tried to avoid interrupting anyone."

Participants voted the two loudspeaker systems as the most performative ones. Opinion was divided between whether a system being performative in a public place was actually a good or a bad thing. One participant explained, "I think it could be fun. I don't get embarrassed in public but some would." Another participant remarked, "I don't want to be a performer. It wouldn't come naturally, but the system works well for a performance. Others always look and listen."

The quantitative results gathered in the post-study interview are provided in full in Table 2.

	Number Entry		Pointing	
	Headphones	Loudspeakers	Headphones	Loudspeakers
Most Solitary	15 (94%)	0	1 (6%)	0
Most Sociable	0	4 (25%)	0	12 (75%)
Favourite Interaction	10 (63%)	3 (19%)	1 (6%)	2 (12%)
Least Favourite Interaction	0	1 (6%)	4 (25%)	11 (69%)
Most Performative	0	5 (31%)	1 (6%)	10 (63%)

Table 2 Quantitative results for questions asked in the post-study interview.

Observations. Participants did not give away many reactions during the study. The main reaction that was observed from participants was smiling and laughter when they were looking at the reaction of spectators (when using loudspeaker versions). There were, however, some participants that appeared a little embarrassed when using some of the systems and attempted to use each interaction technique as quickly as possible. Participants who stood further away from loudspeakers when selecting them generally appeared more comfortable. Overall, participants appeared to stand closer to sound points when using the loudspeaker versions, even though they could be heard from far away. This was also true for both pointing systems, where participants also appeared to approach sound points more closely than when using the number entry systems.

Throughout the entirety of the study, the researcher recorded 528 potential spectators standing nearby that were not participants of the study. Of this number, 216 were deemed to have played an active part as a spectators, being in focused relation to the performance [11]. Spectator acknowledgements ranged from small reactions to stopping to look and listen to what was going on. Table 3 shows the number of spectators that acknowledged the system and/or performer for each interaction technique:

	Number Entry		Pointing	
	Headphones	Loudspeakers	Headphones	Loudspeakers
Potential Spectators	(104)	(130)	(84)	(210)
Spectators in Focused Relation	0	73	4	139
Percentage	0%	56%	5%	66%

Table 3 The number of spectators that were in focused relation with each interaction technique.

Through all of the study sessions, not a single potential spectator acknowledged the performer or system when using the number entry and headphones interaction technique. The headphone and pointing interaction technique was acknowledged by 5% of spectators. These spectators appeared intrigued by the pointing interaction. The pointing and loudspeaker interaction technique gained the most attention, with 66% of potential spectators acknowledging the system or performer in some way. In most of these cases, spectators would begin by looking for the sound source. Once they had found the sound source, some would then attempt to look for the cause of the sound. In some cases, the performer purposely hid or stood further away so that they could not be seen. Acknowledging spectators showed a range of reactions; those standing close to the speakers sometimes gave a shocked or annoyed expression and began to walk away, some were seen smiling and laughing and there were also some spectators that appeared confused.

4.3.5 Discussion

Generally, different participants liked individual aspects of each of the interaction techniques, but there was a clear preference among participants for the more secretive, number entry and headphones interaction technique. In contrast, there was a clear dislike among participants for the more expressive, pointing and loudspeaker interaction technique. The accuracy and level of control for selection –especially when feedback was public– appeared to be a large factor in participants' bias towards number entry. The privateness of the headphone feedback and the ability to control the volume then drove many participants towards a preference for headphones. Many participants said that they were uncomfortable affecting others with loudspeakers, but it is possible that participants only had this opinion due to where the study was conducted. To know whether this is true, we would have to try the system out in a number of different contexts. It could be, that our findings do not hold true in the heritage site context and people may find *Surround You* more enjoyable and more comfortable.

In our study, the main reason the pointing selection did not always work as users had hoped was due to a combination of GPS inaccuracy, network lag between communication devices and more generally, users lack of familiarity with the technique. Throughout the study, users were observed standing very close to sound points, expecting to be able to point at a very small, specific point that we had marked out by the physical locations of each loudspeaker. From this study, we have learnt that one should not pinpoint a very small, exact location in space where something can be activated when pointed at. In exploratory testing prior to the study, participants were not told the location of the loudspeakers. These participants were happy to explore and did not seem to mind if the valid pointing location changed. There was no reference point as to where the pointing should work, so it did not bother participants when it moved around. In future, we suggested that pointing may be more suitable when used with bigger targets in a larger area, where the targets are more spaced out.

Although the only interaction techniques that gained any real spectator attention used loudspeakers, they did tend to grab the attention of at least half of the spectators that passed by. When using loudspeakers with both selection techniques, interesting behaviour was observed in a number of participants. Around $\frac{1}{3}$ of participants purposely attempted to gain reactions from spectators. Most of the remaining participants claimed that they tried to act as inconspicuous as possible. Those who tried to gain reactions tended to stand far away from sound points when activating them. All of these participants found it rather enjoyable confusing or startling people who were nearby. Although some spectators appeared confused or shocked at first, most reacted with a smile or a laugh when they saw the performer and/or the location of the loudspeaker. A few spectators however were witnessed looking annoyed and walking away. In a future experiment, it would be interesting to interview spectators and ask them about their feelings regarding this.

5 Performance for Regeneration

The classic way in which heritage sites –similar to the Hafod-Morfa Copperworks– usually operate, is to either preserve the ruins as they are, or to attempt to restore them. In most cases, visitors to the site can then acquire additional information through visual and audio guides that are available.

At the Hafod-Morfa Copperworks, we have a blank canvas. We have the opportunity to invite people to the site and to experience it before any curated content is developed. Visitors are then able to express their own opinions of what they would like the site to become. By developing new technologies to help visitors interpret the site, we hope to gather valuable visual and audio content that can be shared with all who visit the site. By developing these technologies to be more performative, we hope to give visitors a more expressive medium to evoke memories, enabling them to connect with the site and with others.

So far, we have only used curated animations and sounds that have been created by the system developers, but there is a great opportunity in both of these systems for others to be able to create their own content and share it freely with others. This would give an enhanced feeling of ownership and may possibly make people want to revisit an area to discover new content.

We believe that designing systems to be more performative or with performance in mind is a good way to engage bystanders, effectively turning them into spectators and encouraging them to analyse and understand feedback from the performance. Not only does it encourage spectators to analyse and understand their surroundings, but it is possible that by seeing a performance, a spectator may choose to either join in on a performance or begin one of their own. By using the mobile device as a controller, anyone who owns a compatible mobile device is empowered and can become a performer.

5.1 Initial Focus Groups

On the 7th March 2013, a quarterly gathering called 'Friends of the Hafod' was held. The purpose of these meetings is for the main bodies involved in the regeneration of the Hafod and Morfa Copperworks to provide an update on the progress of their individual projects. It is also a good chance to network with people who are interested in taking an active role in the regeneration of these sites. On this day, a workshop was held to demonstrate the two performative systems that may potentially be deployed at the Hafod Copperworks to facilitate visitor interaction. It was hoped that this session would provide valuable feedback on the acceptability and usability of the prototype technologies.

5.1.1 Technologies Demonstrated

Two prototype systems were brought to the session - a version of the performative projection system from Section 3.2 that we named the *Hafod Torch*, and

Surround You from Section 4.2. The underlying concept of the *Hafod Torch* is similar to our previously mentioned performative projection prototype, but for this workshop session, we removed the QR code functionality from the system and allowed users to choose their animation by pressing and holding a button. In this demonstration application, four animations were included. These animations were chosen carefully and were relevant to the things a visitor would have been able to see at the Hafod Copperworks when it was fully functional. The animations that the *Hafod Torch* projected were smoke, fire, sparks (see Fig. 9) and water.

Fig. 9 The *Hafod Torch* - projected sparks flying from left to right.

Sounds that were used with *Surround You* were closely matched to the kinds of sounds that would have been heard at the Hafod Copperworks when it was still open. These sounds included: a busy locomotive shed, an engine house, barges on a canal and boats navigating a river. If this system were to be deployed for public use, these individual speakers would be placed in their respective locations on site.

5.1.2 Participants

During a networking break, members of the meeting were invited to attend a demonstration/workshop where they could learn about and experience the potential kind of prototype systems that could be integrated into the Hafod Copperworks. Of the 80 people that were there on the day, around 20 stayed for the demonstration/workshop session. These participants were generally middle to old aged and came from a range of backgrounds. There were participants who were academics, technologists, engineers and archeologists, but the majority of participants were general members of the public.

Feedback from these participants was gained through informal verbal comments and questions, and also post-it notes that participants were asked to write feedback on at the end of the session.

5.1.3 Process

For the duration of the session, a presentation was given. There were two break off points during this presentation where each of the systems were given separate demonstration time. Participants in the session were asked to come and stand at the front of the room so that they could play an active role in the demonstrations.

The first system that participants were shown was the *Hafod Torch*. Each of the animations was shown to the group and participants were told why these specific animations were chosen. During the demonstration, participants were asked for suggestions on what other kinds of things could be projected. A conversation then ensued regarding possible changes and additions to the system to improve it.

The second system that participants were shown was *Surround You*. For this system, a demonstration video of possible usage at the Hafod Copperworks was shown. During the video, participants were given an explanation of how the system was working and why particular sounds were coming from certain buildings. After the video had finished, participants were given a real life demonstration of the system working indoors. Again, continuing with the theme, industrial noises were used. During the course of this second demonstration, participants asked questions and actively contributed suggestions.

Participants who were interested in taking a closer look at the systems were given a chance at the end of the session. At this point, participants were given the opportunity to test the systems for themselves. In total, the workshop session lasted for around 40 minutes.

5.1.4 Findings

It became apparent during the demo session that many participants were interested in being able to create their own media for these systems. Instead of only being able to use animations and sounds that had been supplied with the systems, participants claimed that it may be beneficial to allow users to create and share their own animations and sounds through these technologies. One suggestion of the kind of media that could be captured and shared by users at the site was sightings of plants and animals. This participant also suggested being able to record animal noises.

After seeing the *Hafod Torch*, without seeing *Surround You*, the first suggestion that many participants made was to incorporate sound into the same system. In terms of *Surround You*, after watching the demo video, most participants thought that the sounds came from the phone. Participants were quite shocked and excited when they saw the system being used in real life and realised that the sound came from situated speakers. When the real life

demonstration was given of *Surround You*, a number of individuals in the room that were not a part of the session came to see what was going on. In terms of audio choice, participants said that they thought it would be a good idea to hear the voices of workers at the site and for people to be able to share their own stories. One participant explained that they liked both experiences because they were in control of the output. Generally, all participants responded very positively to both systems.

Use for disabled users was mentioned by one participant saying, "you have to think of these things near the beginning. I've seen these new technologies at sites before and people don't think about how disabled people will use them." Another participant commented that both systems were "innovative ideas, easily adapted for those who are visually/auditory impaired."

Concerns that participants had were mainly with regards to the cost of the equipment and whether the equipment was resilient enough to work at the copperworks. Another point that a participant raised was the question of how a user who had an older device would interact with these technologies, and if a visitor without a mobile device could be a part of these interactions at all.

5.1.5 Discussion

Although the majority of participants were of an older generation (50+ years), both the *Hafod Torch* and *Surround You* prototypes were embraced by all that were present. All participants that used the systems found the technologies easy to use with little instruction. The ability for users to create and share their own media seems to be a popular view held amongst most participants. Continually fresh user contributed content sounds like a good way of engaging people and getting them to come back to the site. The only possible difficulty with this is how the content is regulated. As the Hafod Copperworks site will be publicly accessible to those of all ages, it would be important for inappropriate content to be dealt with somehow.

The fact that many more people began to join the session when the live demonstration of *Surround You* began is another indication that the system is good at drawing bystanders in. The audio in the system is fairly loud and when a person cannot see the audio source, they are bound to be drawn in by curiosity. When designing a performative system for public use, the needs of those with disabilities should be taken into account. This could possibly extend as far as creating remote experiences and interactions for those who are not able to visit certain parts of the site.

Regarding the resilience of the technology at the site, careful considerations will need to be made when designing a final product so that these technologies will continue to work under the tough conditions at the Hafod Copperworks. The site has no internet access or power which may cause potential problems.

During the demo session, one participant spoke of the possibility of a visitor not having a device capable of interacting with these technologies. As long as a visitor is in the presence of performer who is using the system, we argue that they are still a part of the experience, but as a spectator. If a visitor does not

have a device capable of interacting and there is no one else around that is performing, we will have to think very inventively of how they may remain a part of the experience.

6 Conclusions and Future Work

The Hafod-Morfa Copperworks in the Lower Swansea Valley is an industrial site of world importance, yet it lies neglected and decaying. As part of the *Cu @ Swansea* project, we have been given the opportunity to develop useful technologies to help visitors interpret the site.

The interesting thing about developing guide technologies for the Hafod-Morfa Copperworks is that the site lies in complete disrepair, with few visual reference points and no interpretation or visitor centre currently present. To help visitors understand the area better, we need to develop technologies that will somehow bring the site back to life, at the same time allowing people to shape and fill this empty space through their interactions and experiences. With this in mind, we have decided to focus on developing and testing performative technologies for deployment there. We have chosen performative design as a base to offer visitors an expressive way of sharing and experiencing the site, engaging others around them in a social experience.

In this article, we introduced two performative systems that we have developed and carried out preliminary evaluations on them in public spaces. In both systems, we have shown potential methods of both developing and evaluating multimodal performative experiences.

A pico projection system, such as the one employed here (see Section 3.2), may encourage people to engage with their surroundings rather than focus on signage or, if using a conventional mobile device, the device itself. Furthermore, there is some evidence that projection might allow groups to enrich their shared experiences and to draw in bystanders.

The choice of locations and attractions for performative projections can clearly impact on the effectiveness of the approach. Future work could explore how to camouflage QR codes to enhance the fun we saw some children having during the hunt for markers. Forcing visitors to stand in "disruptive" locations to project content—for example, changing the flow of others along a pathway—may encourage spectators. Careful stage-craft is needed, though, to avoid annoying bystanders or embarrassing performers.

Pico-projection brightness will remain an issue for some time. To accommodate this, and to further use digital output to prompt physical engagement, we might consider providing more stage direction to users. For example, in the garden context, instead of simply asking people to target the beam on an exhibit, the group could be asked to stand round the plant to provide shade, with one of them cupping their hand around a leaf, further darkening the object before animations begin. As Jacucci et al. [17] discuss, ubiquitous, collocated interaction issues such as these "need to be negotiated through coordination and conflict, which provides opportunities for shared encounters."

When testing different combinations of audio guide interaction techniques, an overwhelming majority of participants preferred using the conventional headphones and number entry technique. The results of this study showed that a large portion of users were uncomfortable with using loudspeaker feedback in a public place. It is possible that the reason for this was to do with the location that the study was conducted in. This finding resonates with the topic of *performing perception* mentioned by Dalsgaard and Hansen [7], where people are not always keen to draw attention to themselves in public settings when using technology. In a visitor centre setting, where others visitors are present for the same information, users may not feel so uncomfortable using such an amplified form of feedback. We will only be able to determine this by carrying out further studies on different contexts.

Many users also reported being uncomfortable with the pointing selection technique employed by *Surround You*. Users claimed that the pointing was not as accurate and did not give them as much control as they had first hoped it would. In future studies, we will attempt to improve the accuracy of pointing by refining the system and more carefully sizing and placing each sound point.

Overall, our results appear to show that the effects of a performance are much more important in drawing in spectators and encouraging them to have an active engagement than the manipulations. The small projections of the pico projector system did not get the attention of more bystanders, however they did encourage a more active engagement between the performer and spectator. In our audio study, *Surround You* gained the most attention from spectators, with over half of the potential spectators acknowledging the system compared to none who acknowledged the standard audio guide style system. The difference in spectator engagement between pointing and number entry with loudspeakers was negligible. Perhaps as part of our future research, we will work on developing even more amplified manipulations in the hope of offering users the tools for more expressive experiences.

Our focus group that contained both members of the public and those concerned with the regeneration of the Hafod-Morfa Copperworks, showed that our prototype technologies were openly accepted and were found easy to use. In this session, spectators were again very responsive to the loudspeaker feedback, proving that loud audio is a good technique of gaining bystanders attention and luring them in.

Our future work will focus mainly on the deployment both of these technologies in situ, at the Hafod Copperworks. This will then allow us to carry out further investigations learning how these systems work, particularly in a heritage context.

Acknowledgements We would like to thank Emma and Jen of the Future Interaction Technology Lab at Swansea University and also our reviewers for their invaluable comments and feedback on this article. We would also like to thank the National Botanic Garden of Wales for allowing us to work closely alongside them and conduct an experiment there. Additionally, we thank all of the participants who took part in the experiments mentioned in this article.

References

1. Ardito, C., Costabile, M., De Angeli, A., Lanzilotti, R.: Enriching archaeological parks with contextual sounds and mobile technology. ACM Transactions on Computer-Human Interaction **19**(4), 29:1–29:30 (2012). DOI 10.1145/2395131.2395136
2. Benford, S., Crabtree, A., Flintham, M., Greenhalgh, C., Koleva, B., Adams, M., Tandavanitj, N., Farr, J.R., Giannachi, G., Lindt, I.: Creating the spectacle: Designing interactional trajectories through spectator interfaces. ACM Transactions on Computer-Human Interaction **18**(3), 11:1–11:28 (2011). DOI 10.1145/1993060.1993061
3. Benford, S., Giannachi, G.: Performing mixed reality. MIT Press (2011)
4. Betsworth, L., Robinson, S., Jones, M.: Pico projection for performative place based services. EIPS Workshop at CHI '13 (2013)
5. Bongers, B.: The projector as instrument. Personal Ubiquitous Computing **16**(1), 65–75 (2012). DOI 10.1007/s00779-011-0378-0
6. Cardiff, J.: Her long black hair. `http://www.cardiffmiller.com/artworks/walks/longhair.html`. Accessed: 2013-08-20
7. Dalsgaard, P., Hansen, L.K.: Performing perception–staging aesthetics of interaction. ACM Trans. Comput.-Hum. Interact. **15**(3), 13:1–13:33 (2008). DOI 10.1145/1453152.1453156
8. Fitzgerald, E., Taylor, C., Craven, M.: To the castle! a comparison of two audio guides to enable public discovery of historical events. Personal Ubiquitous Computing **17**(4), 749–760 (2013). DOI 10.1007/s00779-012-0624-0
9. Fosh, L., Benford, S., Reeves, S., Koleva, B., Brundell, P.: See me, feel me, touch me, hear me: trajectories and interpretation in a sculpture garden. In: Proc. CHI '13, pp. 149–158. ACM (2013). DOI 10.1145/2470654.2470675
10. Goffman, E.: The presentation of self in everyday life. Doubleday anchor books. Doubleday (1959)
11. Goffman, E.: Behavior in Public Places; Notes on the Social Organization of Gatherings. Free Press of Glencoe (1966)
12. GoogleMaps: Google maps street view : National botanic garden of wales. `http://goo.gl/maps/exaFC`. Accessed: 2013-05-15
13. Hansen, L.K., Rico, J., Jacucci, G., Brewster, S., Ashbrook, D.: Performative interaction in public space. In: Proc. CHI EA '11, pp. 49–52. ACM (2011). DOI 10.1145/1979742.1979595
14. Heller, F., Knott, T., Weiss, M., Borchers, J.: Multi-user interaction in virtual audio spaces. In: Proc. CHI EA '09, pp. 4489–4494. ACM (2009)
15. Jacquemin, C., Chan, W.K., Courgeon, M.: Bateau ivre: an artistic markerless outdoor mobile augmented reality installation on a riverboat. In: Proc. MM '10, pp. 1353–1362. ACM (2010). DOI 10.1145/1873951.1874218
16. Jacucci, C., Jacucci, G., Wagner, I., Psik, T.: A manifesto for the performative development of ubiquitous media. In: Proc. CC '05, pp. 19–28. ACM (2005). DOI 10.1145/1094562.1094566
17. Jacucci, G., Peltonen, P., Morrison, A., Salovaara, A., Kurvinen, E., Oulasvirta, A.: Ubiquitous media for collocated interaction. In: Shared Encounters, CSCW, pp. 23–45. Springer London (2010). DOI 10.1007/978-1-84882-727-1_2
18. Jones, M.: Journeying toward extravagant, expressive, place-based computing. interactions **18**(1), 26–31 (2011). DOI 10.1145/1897239.1897247
19. Kawsar, F., Rukzio, E., Kortuem, G.: An explorative comparison of magic lens and personal projection for interacting with smart objects. In: Proc. MobileHCI '10, pp. 157–160 (2010). DOI 10.1145/1851600.1851627
20. Kenteris, M., Gavalas, D., Economou, D.: Electronic mobile guides: a survey. Personal Ubiquitous Computing **15**(1), 97–111 (2011). DOI 10.1007/s00779-010-0295-7
21. KewGardens: Kew gardens mobile application. `http://www.kew.org/visit-kew-gardens/visit-information/garden-guides/mobile-app/`. Accessed: 2013-05-15
22. Lab, G.R.: L.A.S.E.R. tag. `http://www.graffitiresearchlab.com/blog/projects/laser-tag/`. Accessed: 2013-08-15

23. Lozano-Hemmer, R.: Projection artworks. http://www.lozano-hemmer.com/projects.php?keyword=projection. Accessed: 2013-08-15
24. Lucero, A., Jones, M., Jokela, T., Robinson, S.: Mobile collocated interactions: taking an offline break together. interactions **20**(2), 26–32 (2013). DOI 10.1145/2427076.2427083
25. Marentakis, G.N., Brewster, S.A.: Effects of feedback, mobility and index of difficulty on deictic spatial audio target acquisition in the horizontal plane. In: Proc. CHI '06, pp. 359–368. ACM (2006). DOI 10.1145/1124772.1124826
26. McGookin, D., Vazquez-Alvarez, Y., Brewster, S., Bergstrom-Lehtovirta, J.: Shaking the dead: multimodal location based experiences for un-stewarded archaeological sites. In: Proc. NordiCHI '12, pp. 199–208. ACM (2012). DOI 10.1145/2399016.2399048
27. Morrison, A., Oulasvirta, A., Peltonen, P., Lemmela, S., Jacucci, G., Reitmayr, G., Näsänen, J., Juustila, A.: Like bees around the hive: a comparative study of a mobile augmented reality map. In: Proc. CHI '09, pp. 1889–1898. ACM (2009). DOI 10.1145/1518701.1518991
28. Reeves, S., Benford, S., O'Malley, C., Fraser, M.: Designing the spectator experience. In: Proc. CHI '05, pp. 741–750. ACM (2005). DOI 10.1145/1054972.1055074
29. Reid, J., Geelhoed, E., Hull, R., Cater, K., Clayton, B.: Parallel worlds: immersion in location-based experiences. In: Proc. CHI EA '05, pp. 1733–1736. ACM (2005). DOI 10.1145/1056808.1057009
30. Reid, J., Hull, R., Cater, K., Clayton, B.: Riot! 1831: The design of a location based audio drama. Proc. of UK-UbiNet '04 pp. 1–2 (2004)
31. Rico, J., Brewster, S.: Usable gestures for mobile interfaces: evaluating social acceptability. In: Proc. CHI '10, pp. 887–896. ACM (2010). DOI 10.1145/1753326.1753458
32. Rico, J., Jacucci, G., Reeves, S., Hansen, L.K., Brewster, S.: Designing for performative interactions in public spaces. In: Proc. UbiComp '10 Adjunct, pp. 519–522. ACM (2010). DOI 10.1145/1864431.1864503
33. Rogers, Y., Price, S., Fitzpatrick, G., Fleck, R., Harris, E., Smith, H., Randell, C., Muller, H., O'Malley, C., Stanton, D., Thompson, M., Weal, M.: Ambient wood: designing new forms of digital augmentation for learning outdoors. In: Proc. IDC '04, pp. 3–10. ACM (2004). DOI 10.1145/1017833.1017834
34. Rouillard, J., Laroussi, M.: PerZoovasive: contextual pervasive qr codes as tool to provide an adaptive learning support. In: Proc. CSTST '08, pp. 542–548 (2008)
35. Rueb, T.: Core sample. http://www.terirueb.net/core_sample/index.html. Accessed: 2013-08-20
36. Sauter, D.: Light attack. In: ACM SIGGRAPH 2006 Art gallery. ACM (2006). DOI 10.1145/1178977.1179087
37. Scheible, J., Ojala, T.: Mobispray: mobile phone as virtual spray can for painting big anytime anywhere on anything. In: ACM SIGGRAPH 2009 Art Gallery, pp. 5:1–5:10. ACM (2009). DOI 10.1145/1667265.1667271
38. Stahl, C.: The roaring navigator: a group guide for the zoo with shared auditory landmark display. In: Proc. MobileHCI '07, pp. 383–386. ACM (2007). DOI 10.1145/1377999.1378042
39. Taylor, R., Schofield, G., Shearer, J., Wallace, J., Wright, P., Boulanger, P., Olivier, P.: Designing from within: humanaquarium. In: Proc. CHI '11, pp. 1855–1864. ACM (2011). DOI 10.1145/1978942.1979211
40. Väänänen-Vainio-Mattila, K., Häkkilä, J., Cassinelli, A., Müller, J., Rukzio, E., Schmidt, A.: Experiencing interactivity in public spaces (eips). In: Proc. CHI EA '13, pp. 3275–3278. ACM (2013). DOI 10.1145/2468356.2479665
41. Vlahakis, V., Karigiannis, J., Tsotros, M., Gounaris, M., Almeida, L., Stricker, D., Gleue, T., Christou, I.T., Carlucci, R., Ioannidis, N.: Archeoguide: first results of an augmented reality, mobile computing system in cultural heritage sites. In: Proc. VAST '01, pp. 131–140. ACM (2001). DOI 10.1145/584993.585015
42. Wecker, A.J., Lanir, J., Kuflik, T., Stock, O.: Pathlight: supporting navigation of small groups in the museum context. In: Proc. MobileHCI '11, pp. 569–574. ACM (2011). DOI 10.1145/2037373.2037462
43. Williamson, J.R.: Send me bubbles: multimodal performance and social acceptability. In: Proc. CHI EA '11, pp. 899–904. ACM (2011). DOI 10.1145/1979742.1979513
44. Williamson, J.R., Hansen, L.K.: Designing performative interactions in public spaces. In: Proc. DIS '12, pp. 791–792. ACM (2012). DOI 10.1145/2317956.2318076