ABSTRACT
Increasing amounts of geo-tagged social media have led to interest in how that media can be re-integrated into the physical environment. Yet, although location information is often automatically appended to media, little is know about how users consider location in its creation and viewing. Using Graffiti as a design meme, we developed a novel social media service to investigate these issues. A two week field study showed how users incorporated both utilitarian and playful aspects of location into their social media creation, as well as revealing a disconnect between the location-media relationship intended by creators and perceived by viewers. We outline implications of our work for services that seek to repurpose existing geo-tagged social media in the design of novel services.

Author Keywords
Geo-Social Media; Pico Projection; Graffiti; DigiGraff

ACM Classification Keywords
H.5.1. Information Interfaces and Presentation: Multimedia Information Systems - Artificial, augmented, and virtual realities

INTRODUCTION
Whilst graffiti is largely seen as an indicator of urban decay and deprivation, the role it has played as a means of marking and annotating the physical environment is much older and more varied. Social communication, memory aids and blogging have all been identified as reasons for the creation of graffiti in the Roman city of Pompeii [1]. This has led to the much wider definition of graffiti, beyond the legality of its creation, as: “images engraved on a space that did not primarily serve this function” [1]. When considering graffiti in such a way we can clearly see modern examples of these uses.

Contractors often graffiti roads and pavements; spraying in paint the locations of utilities as a way to communicate with later engineers (see Figure 1 (A)). Chalk is used in a similar way to indicate directions to local events, such as bake sales, garage sales or festivals; making visible local knowledge in the environment (see Figure 1 (B)). Advertisers have also used graffiti as a means of promotion. Figure 1 (C) illustrates “inverse” graffiti, where high-pressure washers are used to “clean” graffiti into surfaces. Finally, a variety of mediums are used for self-expression and communication of thoughts and feelings (see Figure 1 (D & E)).

In all cases the use of graffiti is decentralised and anonymous (unless the creator signs their work); with individual images not under the control of any person, including their creator. Anyone is able to alter, modify or erase them. Most importantly, graffiti can be seen as a form of social network with a strong emphasis on location. A person must be in a physical place to create graffiti there, and to see it at a later time. Indeed, many of the examples in Figure 1 only make sense when the graffiti, its referent and viewer are collocated.

Such consideration is relevant when we consider the increasing amounts of social media tagged with a physical location [9]. Researchers have begun to investigate novel ways to re-integrate this content back into the geographic environment of its creation. Rost et al’s Columbus system allowed users to discover flickr (www.flickr.com) photographs taken in and around their current physical location as a way to help explore the environment [14]. PULSE attempted to provide an auditory overview of activities in the immediate vicinity of the user via spoken Twitter messages that were created in the same physical environment [11]. Such systems assume a link between media and the location where it was created, exploiting media to provide new interactions and services to enhance users’ understanding of their current location. However, both represent only two points in an emerging area, which will grow as personal ubiquitous displays, such as Google Glass (www.google.com/glass), become commonplace.

However, the existing social media networks that these novel services will exploit treat geographic location as a secondary
feature. Other than a one-time permission (usually when the app is first run), the user does not need to explicitly consider location when creating media such as photographs or twitter status updates; it is automatically appended by the application. The extent of any relationship between the media and environment is therefore unclear. A user may just happen to be in a location when posting, rather than posting something because of their location. This raises obvious implications for the development of novel location-based services that assume a meaningful link between location and media.

BACKGROUND
Attaching geographic location to social media was first proposed in the GeoNotes system [5]. This used Wi-Fi triangulation to derive a mobile user’s semantic location (office, home, etc.), appending it as an attribute of a “post-it” note message. These messages could then be seen by friends or others who searched for messages related to that location. No user evaluation of GeoNotes was performed, however its approach forms the basis of current mainstream location-based social networks such as Foursquare (www.foursquare.com). Here users can “check in” to a physically close business or named place to earn points and leave comments. As with GeoNotes, users can either “friend” someone and stay informed about that person’s location, or see comments generated by strangers when checking in to a location. Studies into such networks have primarily focused on the issues involved in public disclosure and sharing of an individual’s location. Lindqvist et al. [10] identified the primary motivation for the use of Foursquare was in tracking and monitoring physical location, and collecting badges and points that were awarded when users checked in. Cramer et al. [3] found the same motivations, but also identified more creative uses. To check-in to a place it must first exist in Foursquare. If an appropriate place does not exist the user can create it. Cramer et al. found this encouraged the creation of ‘fantasy’ places that had a geographic location but which did not exist in the real-world (e.g. “‘in your pants’ (a venue ‘in NY’), and ‘Heatpocalypse NYC’ with 9426 check-ins during the 2010 summer heat wave” [3]). Whilst the creation of such places was amusing and creative to some, it was also found to cause confusion for others, and places were often removed or renamed by Foursquare moderators. Similar conflicts were found in the granularity of location. Large places, such as airports, would appear in Foursquare as a single place as well as multiple smaller places (e.g. individual gates and retail units). Again, this created confusion, with comments about a single physical place spread across multiple Foursquare places.

As noted by Cramer et al. [3], it was these loosely constrained elements of Foursquare’s design, such as allowing users to name locations, that brought playful and fun uses beyond what designers had intended. Yet, the intended roles of such networks severely constrain these emergent behaviours. Arbitrary locations, such as the side of a building or half-way along a road, cannot be used. Users cannot leave a drawing in the corner of a park that means something to them, or tag the correct path to assist friends finding their new home for the first time. If places are created for these locations they may, as discussed above, be merged or renamed by moderators.

More recent research has looked at anonymous commenting on places. With Seeburger’s PlaceTagz system [15], users scan a physical QR code sticker left in the environment to access a webpage and leave textual comments about that place. However unlike Foursquare, comments were anonymous and user location could not be tracked or shared through use. Seeburger found PlaceTagz supported conversations amongst anonymous individuals. However, many QR codes were not scanned at all. As the QR codes had been placed in the environment without permission, many were also removed by cleaning staff, effectively deleting the comments as the QR code was the only means of access. As with commercial networks, PlaceTagz constrained the locations users could annotate, and constrained those annotations to only text. Users could not create their own QR code stickers, so were limited to stickers (and places) already in the environment.

We do not know how users think about, or use, location in creating geo-social media. How much do users intend the media they create to relate to the location where it was created, and do viewers interpret such a relationship? Such understanding is important if we are to use social media in the development of new services such as Columbus [14] or PULSE [11]. In addition, by removing the constraints on location, do new uses that leverage the link between location and media emerge, and can these inform new types of location-based services? Existing work fails to provide answers to these questions.

A second issue is how such media are presented, and how this supports links between media and its location. Conventionally, media are presented on a touch-screen mobile device using standard user interface widgets. However, mobile devices can often isolate users from their current environment, rather than encouraging them to consider the relationship between both. Another approach is through the use large-screen displays erected in physical places that act as shared notice boards. Seeburger et al. [16] found these supported interaction amongst temporally separated users whilst waiting at a bus stop. However, these suffer from the same issues as previously discussed. Only predefined locations can be annotated: the physicality of the displays enforces this.

Augmented reality (AR), where digital content is overlaid onto the physical world, would seem to more obviously support any link between media and its location. Whilst AR has traditionally been mediated through a mobile screen, more recent work has considered how visual projection can support a much deeper link. Dalsgaard and Halskov [4] used conventional conference room projectors to overlay museum artefacts with digital content, creating mixed-reality experiences that gave the impression that an artefact was being physically changed (e.g. making a statue of a Viking appear to breathe). Fischer et al.’s SMSlingshot [6] used a novel physical device to allow users to create and catapult text messages at a wall, with a powerful laser projector used to visualise the message being ‘splatted’ and displayed on a physical surface. More recently, small pico projectors have emerged that support the use of projection, and the potential close coupling it provides, in mobile scenarios. Using a body worn Microsoft Kinect 3D camera and pico projector, Harrison et al. [7] have devel-
developed a system that allows ubiquitous projection and interaction with a touch-based graphical user interface on any physical surface in front of the user. Cowan et al. [2] developed a simple sketching program that projected drawings. They found users created interesting interplay between the physical and digital world. Whilst similar in many ways to Graffiti, the images that were drawn could not be fixed to the environment or shared temporally, and did not have the flexible altering rights of graffiti as we described earlier. None of this work has considered how users’ interpretation of the link between social media and the location where it was created is affected by the degree of visual integration between the two. Is there a difference in the understanding of any relationship between media and location if we project it into the environment, or simply present via a touchscreen?

DIGIGRAFF
To investigate these issues we have developed and evaluated a novel location-based social network called DigiGraff. DigiGraff draws heavily on graffiti as a design meme by considering it to be a lightweight social network with a strong location-based component, unencumbered by existing social media concepts (such as like-ing, following, etc.), and without prescribed uses. Users interact with DigiGraff via an app running on an iPhone 4/4S. This connects to an Amazon EC2 server which is used to store and retrieve user-generated drawn tags. In order to investigate the impact of how closely the media and environment are coupled we developed two versions of DigiGraff, each of which varies the visual integration of media with the environment. In the first, DigiGraff (projection), the iPhone was connected to a MicroVision ShowWX+ pico projector which was used to display tags. A wooden block (approx. 1.5cm thick) was sandwiched between the projector and iPhone to remove electronic interference on the iPhone’s sensors. The second version, DigiGraff (non-projector), did not have a projector, instead presenting the tags on the iPhone display. To ensure the physical similarity of both versions a wooden block of the same size was also attached to non-projector version iPhones. Whilst the non-projector version represents a conventional “on-screen” display for media, the projector deeply embeds the media into the environment, allowing us to consider how closely coupled these should be. Users interacted with DigiGraff in three main ways: creating tags, finding and viewing tags, and modifying existing tags. In the following discussion all features are common to both projector and non-projector versions of DigiGraff unless otherwise stated.

Creating Tags
Users generate tags by sketching them on the touchscreen (see Figure 2 (A)). Once drawn, the tag must be “sprayed” onto a physical surface. The user indicates this by pointing the phone at that surface. We use Apple’s CoreMotion framework to determine azimuth and elevation. The projector version also projects the tag to help alignment at this point. From the previous discussion of graffiti a variety of media are used in its creation. Whilst the choice of medium may be artistic, it is also informed by the period of time the creator considers the graffiti to be relevant. The medium used to create graffiti embodies its obsolescence. For example, someone painting a park bench may write “wet paint” in chalk on the ground to alert others not to sit on the bench. The paint will not be wet for more than a few hours, hence the graffiti will soon be redundant. Given the graffiti is written in chalk, it will erode as people walk over it, or when it rains. For road contractors (see Figure 1 (A)), utility markings are relevant until the road is dug up, hence the use of paint. In DigiGraff users must consider the continued relevance of the tags they create. Each time a user creates a tag they must explicitly select a lifetime (ranging from 24 hours to forever) for it, beyond which the tag will “vanish” and no longer be visible. It is this selection of tag lifetime, once the user has selected the correct location to “spray” the tag, that commits it to that location. The tag image, GPS location, orientation (azimuth and elevation) and lifetime is sent to the server. Ageing begins immediately, and the tag is viewable by any DigiGraff user in the same location.

Finding and Viewing Tags
A map view on the iPhone screen shows the location, but not the content, of tags nearby the user’s current location (see Figure 2 (B)). As a user moves within 7 meters of a tag’s location they automatically lock onto it, and can view its content. In the non-projection version the tag image is displayed on the device screen (see Figure 2 (C)). In the projector version the user must align the device to the same direction and orientation where the tag was created. Here the projector acts as a “flashlight”, progressively illuminating the tag as it is passed across its location (see Figure 3), making it appear fixed in the environment. To assist the user the iPhone screen provides assistance in correctly orientating the device azimuth and elevation to reveal the tag (see Figure 2 (D)). In cases where there may be multiple tags within the current 7m radius, the iPhone displays buttons that allow users to cycle through those tags.

Whilst there is an inherent positioning error with GPS, it is the most pervasive way to determine location and is widely used in augmented reality applications. It is possible to instrument an environment with additional sensors, or have the user wear 3D cameras [7] to improve accuracy, but this would restrict the times and locations where users could use DigiGraff. In pilot testing we found, for the iPhone 4 and 4S’s that we used, this error was around 7 meters. Hence why users must be within 7 meters of a tag to view it. Whilst tags may not be projected in the exact same location as created, they will be projected very close by (e.g. further along the same wall) and,
as we apply a low-pass filter to the GPS when viewing a tag, they appear stable and fixed in the environment when viewed.

The visual transparency of a tag is increased as it ages. This ranges from full opacity (alpha value 1.0) when the tag was first created, reducing to almost full transparency (alpha value 0.2) when the tag reaches the end of the lifetime set when it was created. After this the tag will no longer be returned from the server, or displayed by DigiGraff. Thus in the same way as real graffiti tags ‘erode’ as they age, we provide an indication of the tag’s age and continued relevance in the environment.

Modifying Tags
The creators of real graffiti have no physical control over the images they create. Images may be altered or added to by others, or removed by the authorities without consent. DigiGraff enforces this same principle. When viewing any tag a user may choose to alter it. By pressing a button on the iPhone screen, the user is presented with the same drawing tool for creating a new tag (see Figure 2 (A)), but with the existing tag image set as a background. The tag can then be drawn over in any way desired. When pressing the spray button the tag image is replaced. The existing location, orientation, current tag age and tag lifetime are retained.

STUDY DESIGN
To evaluate DigiGraff 13 participants, all undergraduate students of the University of Glasgow, took part in a two-week field study. We specifically recruited students as they would be often on campus and likely to see each other’s tags. Each was paid £30 for participation. Participants were recruited in groups of at least 3 friends. All groups participated over the same two week period and did not know participants in the other groups. Each group spent one week using each version of DigiGraff. Table 1 provides an overview of the groups.

At the start of each week each participant was given a DigiGraff handset (either a projector or non-projector version) and a short tutorial on its use, before being asked to use it over that week as and when they wished. At the end of the week each group was given a semi-structured interview and completed 7-point Likert based usability and social acceptability questionnaires. Logs of interaction with DigiGraff were also recorded on each device. Groups were briefed and debriefed separately, but could view and modify each other’s tags via DigiGraff. Given the public nature of DigiGraff this allowed us to have a mix of users who did and didn’t know each other.

To ensure tags were available at the start of the study 3 volunteers seeded the campus area with 100 tags. To further increase tags, and cover areas away from campus, we used public geo-tagged messages from Twitter as tags. These were distinguished in the DigiGraff map view (see Figure 2 (B)), and were given a standard appearance, orientation and lifetime of 24 hrs. They acted as standard tags and could be viewed and modified (see Figure 2 (D)). Though modifications only existed in DigiGraff and did not propagate to Twitter.

RESULTS
Interviews were transcribed and coded using a framework approach [13], with the uses of DigiGraff, the relationship between tags and the environment, and differences between the projector and non-projector versions used as initial codes. Summary and usage data were calculated from on device log files. Table 2 illustrates mean summary use data for both versions of DigiGraff. In the following, unless stated, we refer to commonalities between both DigiGraff versions.

Overall Usage
As expected, given all participants were students, the majority of use was on campus. However, participants also extended use to other areas, including in and around their homes, or in other areas of the city (such as a railway station). DigiGraff use was opportunistic, with it being used to fill short periods of free time in the day, or when it could be combined with other activities: “(use) tended to be whether I was walking somewhere or didn’t have too much else to do, even just the sort of way you listen to music when you’re walking too and from somewhere”. Whilst the decision to use the non-projector version was described as “thoughtless” and almost automatic, the projector version required a more conscious decision: “with the (non-projector) one it did feel more like you were checking Facebook or Twitter. I can imagine doing it several times a day when you have a spare few minutes. Whereas with the projector it did feel a bit more like you really had to want to see something before, sort of go there”. This was attributed to the added technical complexity of the projector (e.g. having a separate power button).

Participants used DigiGraff alone, physically separated from others, between 70-90% of the time. However, participants tended to enjoy using DigiGraff with friends (who may or may not also have been DigiGraff participants) more, finding it to be fun searching together or trying to interpret the meaning of a tag. In such situations the projector version was found
to offer advantages in sharing tags: “you can show your tag to more people... Not everybody has to climb up around you to see on the small screen where the tag is”.

Motivations to Use DigiGraff

Whilst DigiGraff was used to fill time between other activities, there were a number of motivations for its use. The lightweight nature of DigiGraff encouraging experimentation.

Hide & Seek: Group 1, who were also flatmates, described how they used DigiGraff to create a ‘hide & seek’ game between their flat and campus. As all had classes at different times, they would leave tags for their friends to find later, as well as find and modify tags (see Tag Modification) that their friends had left. Messages were mostly described as jokes that would be meaningful only amongst themselves. These also led to face-to-face discussions when participants met.

Meetings and Rendezvous: A second role, again largely focused on interaction between friends, was the marking of physical locations as meeting points or directions. Participants would create a tag to act as a landmark meeting place to assist other users: “I tagged the Frazer building and I write ‘lunch is here’ so that people can understand where we will have our lunch”. Such uses also extended to drawing arrows or directions on the ground towards such places.

Q&A: Another use was in the creation of tags as a location-based question and answer service, where questions could be pinned to the objects and places they referred to. Here the communication was primarily amongst people who did not know each other. One participant discussed how he had left a note on the library asking where to buy cheap second hand books. Upon returning a few days later, he found an answer annotated onto his tag. He described his use of DigiGraff as: “a source of information where you can just ask something by tagging it”. Since answering a question required the viewer of the tag to both see it and know the answer, many participants reported that their questions had not been answered.

Notes and Feelings: The largest motivation for the creation of tags was to represent something in the environment, or participants’ own feelings or thoughts. There were a wide range of tags, both pictographic and textual, created under this category. For example, a participant in the library used DigiGraff to leave messages about how boring studying was, another drew trees with leaves and flowers to leave in a small park.

Participants often described that there was no intended audience for their created tags, with self expression being the motivation for creation. Although participants were aware that tags may be of interest to friends and strangers. In cases where the tag was explicitly intended for friends, the tags created were similar to those of the ‘Hide & Seek’ use case: sharing jokes or insider stories. When creating tags for strangers, the notion of leaving a historical record for viewers in the far future also emerged. One participant, who spent time in her flat studying for an exam, decided to try to leave tags on the walls. She described her motivation as: “I kind of had an idea as well that if in three years these things are on the mass market, someone might come in and find all these things in my room”.

Exploring the Environment: In complement to the previous use case, the largest motivation to view tags was the desire to discover something about the environment participants were in; using tags as a way of finding out about the activities and people in an area. Such use was described as being similar to the way someone might stop and take a break at a cafe to take in the sights and activities of a physical place: “it’s quite relaxing in a way just to see what’s going on in a social media way. I guess, it’s the same idea about stop, have a break and see what people are talking about, see what people are doing and drawing”. This use case involved tags created by strangers, and largely those created under the ‘Notes and Feelings’ use case. This can be seen as the viewing component of a composite motivation, and this is discussed further in the section on ‘Tag Environment Relationship’.

It is important to note participants did not exist as cliques, using DigiGraff for only one of the discussed use cases. Rather, they moved between the use cases in an organic way, even describing doing so within a single interaction session. The emphasis on self expression and communication was also stressed: “you can basically express emotions or just relate a particular place to a particular idea, that part is absolutely ok, I mean interesting”. In addition, and unlike the conventional following or ‘friend-ing’ in social media, the discussed use cases mix the concept of friends and strangers. Some use cases worked only between friends, whilst others worked only with strangers, whilst others worked with a mix.

Tag Modification

Whilst the use cases of DigiGraff came from discussion around the creation and viewing of tags, the discussion of when and why participants modified tags revealed how these motivations were supported. Unlike existing social media services no explicit ‘like-ing’ or commenting upon a post was supported, yet the first two roles of modification - view recording and shared messages - can be seen as analogous.

View Recording: A common use of modification, discussed in the context of all use cases, was marking a tag as having been seen. Here participants would leave a small mark on the tag, largely as a way of indicating to the tag’s creator that it had been viewed and appreciated: “I do quite like the idea of a person coming along and seeing their tag and someone’s drawn a little thing on it”. Most often such marks were a generic smiley face (see Figure 4 (A)), preserving the anonymity of the tag modifier. However, in a minority of cases initials or symbols were used (see Figure 4 (C)). These acting as a ‘signature’ to uniquely identify the tag modifier.

Shared Messages: Related to View Recording, and most commonly used in relation to the Q&A use case, was the use of Tags as shared geo-notes. Here, one user created a tag with a question or comment, with subsequent users answering it, leaving a comment or asking for more information. Such comments were mostly textual, written using the drawing tools, and thus were limited due to the few characters that could be written by finger. Different colours were often used as a way of improving readability when overwriting the messages. Participants requested that in future new text editing tools should be added to better support this.
In both cases an additional tag could have been left nearby instead. However, drawing on the tag was felt to keep things more continuous than having comments spread over multiple tags. Whilst both of these uses can be seen as analogous to commenting and like-ing, the lightweight nature of modification allowed others to emerge.

**Shared Art:** The lack of ownership over individual tags and their pictorial nature led to the emergence of shared artworks. Here, a participant viewing an image tag would modify it by adding to the concept or image being presented. This could add to the image, completing something the earlier user had started: “There was a drawing of a window with a flower and I don’t remember what I drew, but it was just like completing the picture. I think some clouds over it”. Alternatively, the changes could be more subversive, seeking to change the image, its meaning or what it represented: “I found a bird, it was doing a poo. I added again something to that picture. I put a cigarette in the bird’s mouth” (see Figure 4 (B) and (C)). Such use also extended to Twitter tags (see Figure 4 (D)).

**Tag Moderation:** As with urban graffiti, participants occasionally found tags they deemed offensive or strongly disliked. Here, modification was used as a way to remove tags from the environment, using a single colour to paint over them in the same way a wall might be repainted to remove real graffiti: “I found one, I would say quite offensive annotation, it was underwear, women’s underwear, so I deleted it”. Such modifications were not taken lightly, with participants noting that they would be “disrespectful” if used without good cause.

Whilst this last point extended to all forms of tag modification, it was felt that modifying tags would be seen positively by their original creators. This view was confirmed by participants who originally created tags and later found them to be modified. One participant described reviewing his tags after modification as: “it was pretty interesting to see what were the changes on the tags left by me. I really enjoyed this”. However, no participants discussed tags they created which had been moderated or painted over as offensive.

**Tag Environment Relationship**

A key theme of our analysis was how tags related to their environment, both when created and viewed. In this section we refer only to drawn tags. Twitter tags are discussed later.

From the Likert questionnaire participants responded neutrally that when viewing tags the physical environment helped them to interpret a tag (projector (M=3.8, SD=2.0), non-projector (M=3.69, SD=1.6)), and neutrally that there was often a relationship between the tag and the place where it was viewed (projector (M=2.67, SD=1.31), non-projector (M=3.07, SD=1.25)). When probed deeper during the group discussion, participants were mixed on the proportion of tags they created, from 60% to 80%, were intended to relate to the place they were created. Individual examples of viewed tags helped qualify these results. Whilst participants felt there might, or should be, a relationship between the tag and its location, this relationship was often unclear: “there was an arrow which was pointing to the archaeological building, again, and it just said ‘Duck’. It was just about some kind of direction but we don’t have any idea what it’s about”. Hence, whilst participants may have often intended to have a relationship with the place where a tag was created, this was less obvious, or not meaningful, to those that saw it. In addition, although Digigraff encourages the creation of tags that are relevant to the current location, not all tags are.

**Nature of the Relationship**

It could be assumed that GPS error would account for this discrepancy. Whilst it may account for some, it is unlikely to account for all of it. Participants often discussed location in terms of large objects (e.g. buildings, streets or walls), indicating that they did not intend to have a fine grained spatial coupling between a tag and its location (e.g. drawing a moustache on a poster). Discussions revealed more likely reasons.

In creating tags participants discussed two distinct types of relationship that they intended between the tag and environment: physical relationships and semantic relationships. Physical relationships occurred where participants intended the drawn image to relate only physically to the location where it was placed, with the objective being an interesting interplay between the physical world and the drawn image: “it was in terms of how they fitted round the building, or the street, or whatever. Things like drawing a snake along the side of the kerb and things like that. It was trying to physically fit it into the environment in a way that seemed weird and interesting”. When viewing tags participants found physical relationships to be easily relatable to the location where they were found: “Just in the pictures that people drew, they’d be drawing something that you saw. Even if it was just a tree or something like that you could have a guess that it was one of the trees that were there that they’d drawn”.

With semantic relationships, although there is a physical component, understanding the relationship between the tag and location relies on a shared understanding between the creator and viewer. This may be formed through the placefulness [8] of a physical environment, sharing an understanding of its people and activities: “I found a tag with a quote from a Bulgarian author, and actually there was nothing in common with the location, but I found it on campus, so I relate...
it with that there are so many international students”. Alternately, the shared understanding can be formed through personal friendship. For example, a participant who was studying for an exam left tags in the library in which she expressed her current mood. Whilst in both cases there is a relationship between the environment and tag, fully understanding that relationship depends on the shared understanding of the creator and viewer. Whilst placefulness might be easily “picked up” by a visitor to a new location, shared understanding through friendship is deeper and takes longer to develop.

Assumed Environment Tag Relationships

Whilst participants “fitted in” DigiGraff to spaces between other activities, the perceived busyness of a place often influenced the decision to take out and use DigiGraff. Participants assumed that busy places in the real world would have a correspondingly larger number of tags in DigiGraff. This assumption was often valid when on campus, where other DigiGraff users were active. However, in other locations, including supermarkets or retail parks, this was not the case. Such consideration illustrates that participants not only found a relationship between the tags and environment, but also inferred the existence of tags based on the environment. This relationship is therefore two-way, and not restricted to only interpreting tags in relation to their immediate environment. It may also be richer than simply interpreting the density of tags based on the visual appearance of a place, however a much larger deployment of DigiGraff would be necessary to study this.

Projection Encouraged Relationship Thought

How individual tags relate to their environment is complex, and not always obvious when viewed. Hence participants did not find a significant subjective difference between the tag-environment relationship with either version of DigiGraff. However, participants did rate their subjective intent to relate tags to the environment (either spatially or semantically) as significantly higher with the projector version of DigiGraff (T(12)=3.5 p=0.04). This was largely attributed to the earlier discussed complexity of the projector version (see Overall Usage section). This raised the effort required to make a tag, and thus participants would only do so when they had something meaningful to create: “It’s just if you have to put more effort in, then I don’t think you will go through the whole process just to make a single line or something like that”. The use of the projector also illuminated new use cases that focused on a spatial environmental relationship with the tag, and which would not have been possible with the non-projector version. For example, using spatially placed tags to act as directions (such as in the Meetings and Rendezvous use case): “things like the signs leading up to the computer science building, the tags saying ‘cake stall this way’. That was quite a nice way of using it that I hadn’t thought of before”. In this case the spatial relationship with the tag and environment could only be exposed through the projector because of the deep embedding of the tag into the environment.

In cases where participants viewed a tag with a mostly spatial relationship with the environment, the tighter integration afforded by projection was discussed positively: “I mean, we look at screens every day but it’s just more interesting to see it physically on something, on the place where it was actually created”. The increased effort required to view a tag with the projector, by having to correctly adjust its orientation to “reveal” the tag via the projector, was also seen as a positive aspect, requiring attention switches to the physical environment to search for the tag. As such, tags were often seen as parts of the environment rather than just projected images: “It’s kind of unexpected in a way that there is nothing there and you shine a light on it and suddenly there is.”. With the non-projector version this relationship was less clear, as the tag could be: “anywhere around you, it could be behind you, in front of you”.

For tags without a relationship, or with a semantic link between the tag and environment, the projector was seen as less useful. The expense of aligning the projector with the environment, seen as a positive where a strong spatial relationship existed, was seen as inconvenient without the benefit of the environment adding to the tag’s interpretation. In such cases presentation on the screen was seen as better. Overall, both presentation methods were seen as necessary: “it depends on the tag itself whether it’s going to be best as a projection”.

Temporality in Tags

Each time a participant created a tag they had to provide its temporal lifetime, between 1 day and forever, which determined how long it would be visible. No significant difference in creation time was found between DigiGraff versions. The graph in Figure 5 shows the combined tags created with each temporal lifetime. Discussion with participants agreed with this trend, with a range of lifetimes used, but with a strong preference towards shorter lifetimes.

There was a general view that as tags got older they would have been seen by those who were interested and should be forgotten. This was described as analogous to the way in which timeline based social networks (such as Facebook) work: “maybe there is not much going on on your wall, your post is at the top for a month at the very most. But after that, the natural flow of things just means that things get pushed down and forgotten about.”. The difference with Facebook however, is that previous posts, even those several years old, can still be viewed by searching through a user’s timeline. DigiGraff does not support this. When tags reach the end of their temporal lifetime they can no longer be seen by any user.
Only tags that were created with the ‘forever’ temporal lifetime option will continue to be visible in the same way as Facebook or Twitter messages. However, the use of ‘forever’ was described as ‘scary’ and ‘a commitment’, with participants concerned at who might see the tag and the repercussions it might have on them at a future date. Given the general view that tags should not last forever, two considerations influenced the temporal life they were given. The first was how ‘interesting’ participants believed their tags to be, with longer lifetimes being given to more interesting tags: “If I liked it (the tag) a lot I wanted it to stay for longer, and if it was just simple words or something less meaningful, I just wanted it to stay for one day.” Related to this was the predicted continued relevance of the relationship between the tag and environment. As with our earlier discussion, consideration was discussed in terms of both continued spatial: “I was trying to tag that tree. I thought it would be there even in 20 years time, probably it would become bigger etc.”, and semantic relevance: “if I was organising things around campus I would make them (the tags) last for the duration of the event.” Whilst using forever as a lifetime was generally avoided, with only 10% of tags created with it, it was strong scores on all these factors that encouraged its use.

Twitter Tags
In addition to drawn tags participants could view geo-tagged Twitter messages as tags. Whilst these increased the potential number of tags that users could encounter, they also provided a comparison between the geographic presentation of social media where the location of its creation is secondary, versus DigiGraff, where geographic location is a primary attribute.

The overwhelming response was that Twitter tags were boring with either version of DigiGraff, and all participants expressed a desire for them to be removed. Messages often failed to make sense, either as they were unrelated to the place they were found and lacked context, or were parts of a conversation that didn’t make sense in isolation and to which participants could not contribute even if they wanted to.

A minority of Twitter messages however were found to be interesting. As with PULSE [11], messages that obviously related to or mentioned a location were found to be more interesting. “If I liked it (the tag) a lot I wanted it to stay for longer; and if it was just simple words or something less meaningful, I just wanted it to stay for one day”. Related to this was the predicted continued relevance of the relationship between the tag and environment. As with our earlier discussion, consideration was discussed in terms of both continued spatial: “I was trying to tag that tree. I thought it would be there even in 20 years time, probably it would become bigger etc.”, and semantic relevance: “if I was organising things around campus I would make them (the tags) last for the duration of the event.” Whilst using forever as a lifetime was generally avoided, with only 10% of tags created with it, it was strong scores on all these factors that encouraged its use.

Location Sensing Issues and Improvements
Whilst DigiGraff was viewed positively, it was not without issue. The inherent error in GPS meant that projected tags were unlikely to be seen in the exact same location on temporally separated viewings (e.g. when revisiting a tag in the Q&A use case). Although GPS filtering helps to make tags visually stable, they were in different places on subsequent viewings was noticed by participants, and may have restricted the fidelity that they intended between the tag and environment. Participants often discussed the tag-environment relationship in terms of relatively large physical objects (e.g. buildings and walls). In the minority of cases where multiple users (each with a DigiGraff projector handset) were exploring the same place concurrently, they noted the same tag could be simultaneously projected by each handset in slightly different places. Future development of visual camera tracking systems (e.g. [7]) will help solve this issue, but these are current tools cumbersome to deploy in a study such as DigiGraff. Due to the ‘looser’ relationship between location and media, such issues did not occur with the non-projector version. Additionally, although new and modified tags were always immediately sent to the server, and available to the DigiGraff handset used to create or modify the tag, other DigiGraff handsets would need to refresh tags with the server first, either at app launch or when the user moved >30m from his/her current location. This led to frustration when users were collocated, as one user could not find a tag that they knew had just been created by another, breaking the illusion of embedding media in the environment. Although the majority of DigiGraff use was alone, use with others was preferred. Therefore keeping all handsets in sync is an important requirement.

Whilst GPS generally worked well outdoors, allowing for unconstrained tagging, it provides poor accuracy indoors. Participants were informed that DigiGraff would not work well indoors. Yet, as discussed later, several still used DigiGraff indoors, or in closed, covered spaces. Tags created indoors often appeared outdoors, or could not be re-found by participants in the same way as outdoor tags. An original assumption of our work was that participants would only want to mark locations outside, however this was clearly not the case. These issues limited the indoor interaction potential and, as ubiquitous indoor location sensing technologies are developed, there is value investigating more deeply how DigiGraff like systems are used indoors. As one participant noted: “I think great things can happen indoors as well”.

Social Acceptability
Social Acceptability relates to the evolving interplay between the motivation to use a technology and the social constraints in particular situations on the use of that technology [12]. For example, it is generally not socially acceptable to make a telephone call during a theatrical performance. Whilst the social acceptability of established technologies is well understood, at least tacitly, social acceptability of nascent technologies such as pico projectors is not. Only Cowan et al. [2], in a field study on how users might more generally employ pico projectors, considered social factors around projection. They found that the content users would choose to project changed on who the user was with, and provided examples where users chose not to project content based on their situation (e.g. projecting onto a police officer). However, in DigiGraff users do not determine what content to project, or even know what it is until it is projected. Therefore consideration of DigiGraff’s social acceptability is important, as if users are unwilling to use projection in public, any benefits brought by its deep embedding of data into the environment will be lost.

In addition to discussing social acceptability in the interviews, we administered a questionnaire based on the work of Rico and Brewster [12]. Participants were asked to rate on 7-point
Likert scales their social comfort in creating, finding, viewing and modifying tags at different locations (at home, outdoors in public, indoors in a public place) and in the presence of different groups of people (alone, friends, strangers). Wilcoxon matched pairs tests were carried out to compare the projector and non-projector responses for each question.

Irrespective of where or with whom the non-projector version was used, few social acceptability issues were identified. Participants found they could easily hide the block attached to the iPhone, so they appeared to just be using a phone. The social acceptability of the non-projector versions was therefore considered the same as a smartphone, and discussion of the projector versions should be considered in relation to this.

When used at home or indoors in a public place, no significant differences were found. Indoor use was much lower than outdoors, largely as participants quickly found that whilst GPS was reliable outside, it was very unreliable indoors. However, situations where projection indoors was identified as inappropriate did arise: “The first night, I used it inside by trying to project on the window of my neighbours, and it was like a little bit frightening for the person”. Using the projector around strangers was also identified as causing social discomfort: “I turned it on while I was at the gym, talking to the receptionist and I was kind of worried they would think that I am doing something bad...... I tried to hide it under the desk”.

In cases where participants used the projector with friends outside they found that this increased their social comfort: “It didn’t bother me actually, other people. I think it helped we were in a group and looked like we were doing some kind of group project”. This provided a sense of a ‘gang’ mentality: “(other people) were mostly scared. Not scared, but they weren’t sure what was going on. We knew what we were doing and we found it pretty amusing”. Similarly, when using the projector alone outside, participants noted that this didn’t cause any feelings of social discomfort.

Outdoor use revealed significant lower ratings for projection over non-projection only when DigiGraff was used in the presence of strangers (creating (p=0.021), searching (p=0.021), and viewing (p=0.031)). Participants found that using the projector caused them to perform actions that were not disguisable as using a standard mobile device. When the projector was used alone, the need to perform physical actions when searching for tags, rather than having them presented on-screen, was noted as a reason for feeling uncomfortable: “I had to physically turn around. So I was in the middle of the street just turning round, and that was embarrassing”. The use of the projector itself was also cited as another: “the projector one in the dark was just so bright and obvious”. Participants also had no idea what a tag was or its size until it was projected: “if you don’t know what size it’s going to be... So all of a sudden, there could be this massive duck on the wall, and it’s really embarrassing”. However a minority of participants liked the projector because it was different and drew attention to them: “I was completely the opposite, because with this I wanted to show I have something they don’t have”. Whilst participants were conscious of drawing attention, the reaction of strangers was described as: “generally just feeling that people were giving you slightly strange glances. Nothing more than that”. When third parties did interact with participants this was borne from curiosity about DigiGraff.

Although there are situations were using the projector drew attention to participants and decreased their comfort of use, the use of projectors was not socially unacceptable. For both versions of DigiGraff the mean score for each Likert rating fell well within the upper half of the scale (very to neutrally comfortable). As pico projectors become more common, their social acceptability will evolve, with use less likely to draw attention. As one participant noted: “I think it’s one of these things that if everybody had one, I wouldn’t feel self-conscious doing it because everybody would be doing it. But on my own it was - I’m aware I’m doing something unusual”.

However, this work indicates that projection of social media is something users are willing to do.

**DISCUSSION**

Our goal in the study of DigiGraff was to consider graffiti as a lightweight and unconstrained environmental annotation system, allowing us to understand how, and in what way, users consider location in the creation of social media. Our results have significantly contributed to this aim.

As users were required to consider location when tags are created, we would expect the number of tags related to their environment to be higher than with other social media services where location does not need to be explicitly considered. Yet, at least 20% of the tags created were described as having no intended relationship with the place where they were created. Simply requiring users to think about location when creating tags does not mean those tags relate to the place they are created. This has implications for future services, such as PULSE [11] and Columbus [14], that wish to exploit geo-tagged social media for novel services, that the relationship between media and location cannot be guaranteed. In cases where the social media service does not require users to consider location explicitly, such as Twitter, the proportion of geo-tagged media that have a meaningful relationship to their location is likely to be much lower. Even when there is an intended relationship to the environment, this may not always be obvious when viewed. Only 20% of participants described an obvious relationship between tags and the place where they were seen. Whilst our analysis revealed the spatial and semantic issues of this relationship, the multiple uses of DigiGraff may also affect it.

We did not define an *a priori* role for the use of DigiGraff, and this encouraged participants to develop their own use cases without the constraints that an ‘official’ use case would have brought. These ranged from utilitarian, to artistic and whimsical. More interestingly however, was that participants did not stick to only one role but moved between them, often within the same session of use. In the context of placefulness [7], where a physical space is embodied with a role, we can consider that participants created multiple, concurrent places - through subsets of related tags - within the same physical space. A distinction is that these digital places can exist within the same physical space at the same time, with users
dynamically moving between them whilst in the same geographic location. We can consider the issues in Foursquare, as identified by Cramer et al. [3], as similar. Yet the fluidity and speed of how DigiGraff users moved between these multiple digital places raises questions on how to best support them, without restricting their use. Viewing tags when the user is in one digital place could cause confusion if the tag was created in another. This may have also contributed to some of the discrepancy in the tag-environment relationship when creating and viewing tags, although explicit investigation would be required to understand its extent. How to support this without restricting use is a non-trivial but important problem to solve.

Better understanding of how content relates to location would also help determine if that content should be deeply embedded. In directly comparing deep embedding (via projection) with ‘lossy’ embedding (via the touchscreen), the spatial relevance of the tag with the environment was the key factor in determining if projection (and deep embedding) was useful or not. Where tags strongly spatially relate to the environment, deeper embedding is better, strengthening this relationship, and in cases exposing a relationship between the tag and environment which would not have been seen if the tag was displayed only on-screen. Where there is no, or a semantically unclear, relationship between tag and environment, there is little advantage in deeply embedding media, with the vaguer ‘around here’ relationship afforded by the device display being preferred. Although projection as used here brings particular issues, it is likely that this also extends to other forms of AR (e.g., drawing tags over a live video), which attempt to closely fuse digital information to the real world. In practice, multiple techniques that can vary the closeness of the tag/environment relationship are optimal.

In conclusion, DigiGraff has significantly advanced our understanding of the role of location in social media, validating the use of graffiti as a lightweight means of augmenting the world. Whilst the study raised important future research issues, participants were engaged and stimulated by their use of DigiGraff. Whilst seeing it as a form of social media, they also found it to be “fun” and “cool”; offering new ways of interacting and communicating. As one stated during her final interview: “I will somehow miss it because I got used to it”.

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