Traces: Studying a Public Reactive Floor-Projection of Walking Trajectories to Support Social Awareness

Beatrice Monastero & David K. McGookin

Department of Computer Science

Aalto University, Espoo, Finland

{firstname.lastname}@aalto.fi, www.davidmcgookin.net

Figure 1. Examples of interactions with Traces. a: Implicit interaction by walking through the lobby. b: A person engages passively, stopping to observe the projection. c-d: Traces generated by a group of visitors during an exceptional event. e: A projection representing a regular working day. f: A user interact playfully by drawing (active engagement).

ABSTRACT

Walking trajectories have been used to understand how users interact with public displays. However, it has not yet been studied how displaying them *in-situ* could affect users' awareness about others' presence and activities. We present the study of an interactive public floor-projection called Traces. Traces projects the walking trajectories of individuals as they pass through the lobby of a university building. We investigated Traces through a 6 week in-field study. Our results outline how different uses and understandings of Traces contributed towards its appropriation as a glanceable display for social awareness. We outline design suggestions that future designers should consider to support social awareness with public displays.

Author Keywords

Public Display; Reactive Display; Behaviour Mirroring; Projection; Traces; Social Awareness

ACM Classification Keywords

H.5.1. Information Interfaces and Presentation: Multimedia Information Systems - Artificial, augmented and virtual realities; H.5.2 Information Interfaces and Presentation: User Interfaces - Interaction Styles

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivs International 4.0 License.

CHI 2018, April 21–26, 2018, Montréal, QC, Canada.

© 2018 Copyright is held by the owner/author(s).

ACM ISBN 978-1-4503-5620-6/18/04.

<https://doi.org/10.1145/3173574.3174061>

INTRODUCTION

Although the HCI community has considered supporting social awareness in a space before, work has focused on changing activity patterns using social pressure, such as persuasive encouragement to go for coffee breaks at the same time as others [14], or visualising how many people take the stairs or elevator to encourage healthier behaviours [38]. Other work is more explicit in representing higher-level activities, such as through noticeboards or forums [23,27,37,49], or by supporting connection between people based on common or needed skills in co-working spaces [4,25]. However, these often constrain understanding of the space to those high-level activities.

Publicly visualising low-level human activities (i.e. where and when people walk – walking trajectories) to provide public awareness of others' presence and practices in a place is less considered. However, recording and studying low-level activities, such as mobility patterns, is an important analytical tool for researchers studying engagement with public displays [2,4,34,38,48]. Such studies have led to understanding proximal zones, modalities of interaction around displays [29] and trajectories of interaction [2,3]. They are of such value researchers have developed systems that can anonymously and automatically capture mobility patterns around public displays for analysis [34,45,46]. Given the importance of mobility patterns to understand how people engage with public displays, it is feasible to consider how mobility patterns could themselves become public displays, and how their interpretation impacts and informs the understanding of a place by its occupants.

However, existing public interactive display research raises issues in doing so. Displays often radically change the use of

a space where they are deployed, whilst our goal is to largely reflect existing uses of a space. Most public displays also focus on active interaction [9,29,42]: users must actively engage with the display (requiring them to both understand that it is interactive, and how to interact with it). This requires time, such as observing others to understand how to interact [29]. Public buildings (such as offices) however, have a mix of occupants, including those that work or regularly visit (recurrent users), as well as those that visit infrequently (non-recurrent users). The primary purpose of such users is to 'do work' rather than spend time interacting with a public display. This is unlike many public displays that are presented as 'events', where interacting with the display is a primary purpose [19,30,45]. Because of this, such interactive displays are often only active for a short period [4,6,19,30,45], or individuals interact only a few times [9,26,33], so only a novelty effect [9] is studied.

RELATED WORK

In considering how to visualize mobility patterns *in-situ*, we first discuss the value of walking trajectories as a display of social behaviour, and relevant issues in public embedded displays - motivating why reactive floor visualisations are a valuable approach to display them. Finally, we discuss new interaction possibilities to support longer-term engagement, and the importance of studying beyond initial novelty.

Walking Trajectories as a Reflection of Public Practice

How and where individuals walk through a public space is linked to the structural characteristics of the space, the activities in it, and personal relation to the space (e.g. an employee would move through a building in different ways than a visitor) [3,24]. Walking trajectories therefore reflect individuals' situated practices, and have long been considered as an analytical tool by researchers to study how individuals interact with novel technologies [2,3,29,30].

Walking trajectories by themselves are ambiguous, they show where people walk, but leave the purpose of that walking open to interpretation. However, there is value in presenting ambiguous representations of data to individuals and leaving its interpretation open [5,15,27]. Williamson and Brewster [44] mapped the movement of a performer to the movements of a virtual fish displayed on a mobile device. The ambiguity of movement engaged the curiosity of users towards what it represented, and supported users to derive personal meaning [16]. It is likely that ambiguity in walking trajectories would also support individuals in creating personal meaning from the visualisation. Whilst in Williamson and Brewster's system [44] the observer was displaced from the performer, presenting information locally, in the place it refers to, can better support the interpretation of both [21,27,41]. In a behaviour change study, designed to encourage building occupants to use the stairs rather than an elevator, Rogers *et al.* [38] found situated an ambient displays of raised and lowered balls provoked reflection and behaviour change, despite ambiguity in the visualisation.

Prior work suggests ambiguous representation of individual behaviour can encourage curiosity and personally meaningful interpretations. Presentation in context can also enhance this. However, how walking trajectories could be displayed to support public awareness of others in, and their use of, a space by its inhabitants has not yet been considered. This motivates our first research question **RQ1: What is the impact of a visualisation of low-level walking trajectories on supporting social awareness in a public building?**

Fostering Engagement Through Implicit Interaction

A second issue is how to effectively present walking trajectories *in-situ*. Existing research often uses conventional screens, such as LCD monitors attached to walls, to display higher level attributes of an activity (such as finding others with particular skills in a co-working space [4,25], or communicating specific events in a shared space [23,37,49]). These often suffer from display blindness, where the display is not noticed or 'filtered out' [28,31]. Tangible [17,28,37] and embedded displays [10,45], as well as presentations in alternative locations [38], can be an effective way to overcome this. For example, Rogers *et al.* [37] visualised residents' opinions about their neighbourhood by drawing them in chalk on the road surface. Although we do not usually pay direct attention to the ground, we must regularly pay attention to it to move safely. Rogers *et al.* [37] found the visualisation, in part because it was embedded in the road, engaged residents more than a wall display. Floor displays, either as static fixed stickers or as non-interactive projections, are often employed as advertisements, or to show efficient navigational routes through complex buildings [39,47].

Fatah and Kostakos [9] developed an interactive digital carpet, embedded with LEDs, that reacted to walking. They found the carpet acted as a "ticket" [40] when placed in a city square, encouraging encounters between co-located individuals. This raises a final issue related to the mode of interaction itself: public interactive displays often require active engagement (where individuals must actively interact with the display [42]) in order to generate content (i.e. firing a message onto a graffiti wall projection [10]). Whilst individuals can engage passively by observing others interact, there must be some active users engaging to see any effect on the display. Such installations are also often designed as "events", where individuals will go with the purpose of explicitly interacting, with "facilitators" to encourage active participation [48]. This is less likely to be sustained with people in a building who often have primary goals other than interacting with the display, and have limited time to actively engage with it. The use of reactive feedback, where individuals interact with a public display, in implicit ways (either unconsciously not noticing interaction, or consciously but ignoring it while pursuing other practices [9,11,42]), may be a better approach. However, it has not yet been studied how basing interaction on reactive feedback itself might overcome the need to have active participants constantly interacting to have value.

Would individuals interact implicitly (simply by walking by), so that the visualisation would reflect how the space is generally used and support the interpretive ambiguity already discussed? Or would interaction be dominated by active engagement, with individuals creating walking trajectories in playful ways, radically changing how the physical space is used and failing to reflect contextual everyday practices? This motivates our second question **RQ2: Does the reactive floor projection reflect existing uses of the space or significantly redefine them?**

Supporting and Studying Public Appropriation

As already discussed, public buildings contain a mix of both recurrent users (such as employees) who will be present often and regularly, and non-recurrent users (such as visitors) who might be present only once or infrequently. As most existing work studies interactive public displays as events (so individuals will interact only a few times, such as with Fatah and Kostakos' interactive carpet [9]), how use changes over prolonged exposure, and how to keep people engaged for longer periods of time, is understudied.

Research has shown how users appropriate display technologies in phases. Initially users explore by interacting more often with a system to build up their knowledge about it, then establish a particular use [7,12]. In some cases use is abandoned, in others, users become habituated to the presence of the display and access it only when needed (e.g. checking the heating temperature if it feels cold [12]). Appropriation happens through collaborative and creative activities influenced by social context [8]. Recurrent users can change the meaning related to the technology (semantic), how they use it (behavioural), or how they modify the technology itself (technological) [32]. Conversely, non-recurrent users may not be able to appropriate such displays, given the limited interaction and understanding they will have.

Whilst, as already discussed, ambiguous information can support meaningful interpretation, forming these can take prolonged exposure [7]. How would non-recurrent users interpret such information? Would they identify value, or would their interactions disrupt the interpretations recurrent users found? Whilst research has argued the need to improve understanding of technological appropriation in public spaces, where users and practices are heterogeneous and dynamic [1,12,22,32], there is a lack of practical guidance on how to support this through embedded media. Although research has considered how users interact in different ways with wall displays (i.e. implicit, passive, active interaction) [11,29,42], work has not yet focused on how recurrent interactions may evolve over time in relation to appropriation.

To address these issues we derive **RQ3: How does understanding and use of the system evolve over time, and differ between recurrent and non-recurrent users?**

TRACES

To answer our three research questions we designed Traces, a reactive floor display of walking trajectories. Traces consists of three Microsoft Kinect cameras and three digital projectors (Optima HD141X HD, each running at 1920x1080p resolution) fitted to the ceiling. As individuals walk through the Kinect's field of view, their trajectory is recorded and projected onto the floor in real time. Traces can detect multiple simultaneous interactions, but due to privacy concerns, does not try to uniquely identify individuals or their characteristics (e.g. gait or size). We prototyped multiple visualisations for Traces, including different colours and visual forms.

Figure 2. Map of Trace's projection area in the Design Factory's lobby. The blue area illustrates the locations and areas covered by the three Kinects and projectors.

However, as the space the system was deployed in provided three main directions of movement (Figure 2), each of which led to different types of spaces and which could be passed through very quickly, we decided to focus on representing the volume (amount) of footfall and the pace (speed) of that. Therefore, Traces projected a series of white dots behind the user as they walked. At a regular indoor walking speed (~ 1.4 m/s) the dots merge to form a solid line, whilst at faster speeds they will appear as a line of distinct dots. Traces are persistent, but gradually fade over time, fully disappearing an hour after creation (Figure 1). In this way, the floor represents a snapshot of movement activity over the previous hour. Whilst we could have had a more complex visualisation, we wanted to keep it relatively simple and allow participants to suggest additional aspects that might be useful based on how their understanding evolved during the study.

STUDY OUTLINE

Traces was installed in the lobby of the Design Factory, a university building with shared facilities for student-centric learning, prototyping, open courses, seminars and research projects. The multi-purpose nature of the space means it is popular with a wide community of international researchers, students, staff, entrepreneurs, company representatives and general visitors, and has a mix of recurrent and non-recurrent users. The deployment area (covering 18m^2) covered the main entrance of the building, which allows passage to event/seminar space, co-working benches and routes to the

various workshops. Traces was installed for a period of 6 weeks over summer. It ran continuously each day from 8:30 to 19:00.

Data Collection

We employed several methods to capture and understand interactions with Traces: Interaction data logs, regular video observation, opportunistic interviews with visitors and periodic discussions with a group of recurrent users. This allowed us to gain insight into how users interacted with Traces, as well as how that use evolved over time for recurrent users. Each data source was separately coded. Data from non-recurrent users was coded separately from recurrent users. We developed an initial set of codes from the research questions (Traces Interaction, Understanding of Traces, and Purpose of Visit to the Design Factory). For recurrent users, evolution of understanding was an additional code. We iteratively coded as outlined by [36], with new and refined codes emerging during the process, and using [20] to guide this work. We held regular walkthroughs of the current coding state with the wider research team. This review was intended to reduce individual coding bias and identify further codes.

These data were then triangulated to help determine answers for the research questions. Observations and opportunistic interviews with visitors aimed to provide an overview of Traces use and understanding (RQ1, RQ2). Whilst periodic interviews with recurrent users aimed to help understand how use and understanding evolved over time (RQ3), and contextualise observations and interviews.

Regular Video Observations and Interaction Data Logs

We regularly observed and video recorded interaction with Traces. We recorded a 2-hour period on 3 randomly selected days each week. We chose not to video record continuously in order to minimise the impact introduced by the presence of the researcher and the additional camera that was clearly observing (due to ethical requirements notices were required to be placed describing this). A seating area to the side of the installation provided a discrete location to observe and record interactions (see Figure 2). Whilst data logs (from the Traces system) only recorded explicit interaction (when someone walked into the camera frame), we did use this to gain an overall understanding of the use of the Design factory (see Figure 3), and ensure that our video recording sessions were representative, avoiding bias in observation towards particularly busy, quiet or exceptional times.

Opportunistic Interviews

During the video observation sessions we selected people who had interacted with Traces to take part in a short (10 min.) semi-structured interview. A total of 28 participants were interviewed, median age of 26, 2 over 50, 7 females, of different nationalities and relationships with the Design Factory (8 students, 8 employees, 7 undertaking personal projects, 5 visitors). Participants completed a demographic questionnaire including frequency of visits to the Design Factory since the activation of Traces, approximate number

of interactions with Traces, and familiarity with similar installations. The semi-structured interview served to gather data about how participants discovered, interacted, and interpreted Traces, and their opinions about it (RQ1). These, along with the video of how these users had interacted, were used to determine a set of interaction codes that were used to code the remaining video recorded interaction instances. All interviews were audio-recorded, transcribed and analysed through open coding [13], aiming to identify trends in users' attitudes towards the interactive systems in terms of understanding, use and feeling (personal opinions about it). In the results we prefix these participants as OI (Opportunistic Interview).

Figure 3. An overview of typical interaction levels with Traces (as taken from Traces logs) showing how interaction varies over a day. Showing how this varies on a closure day (during 2 weeks of the study), a regular day and an exceptional event day (where an event, conference or other event took place).

Recurrent Users

To understand how use evolved over time, we recruited a group of 7 recurrent users (2 females 5 males, aged 21-31, international composition) who had different relationships with the Design Factory, and would be visiting the building during our study on a regular basis.

Participants were provided with incident diaries to record any interactions with Traces that they felt were interesting. Participants were interviewed in total 5 times over the deployment to understand how attitudes towards Traces evolved, together with their increasing familiarity with it. The first interview took place before Traces had been deployed to gain baseline understanding of how users viewed the space. All interviews were recorded, transcribed and analysed through an open coding strategy [13]. We validated how these users understanding of Traces evolved by comparing how opportunistic interview participants described interacting and their prior experience with Traces. We refer to such participants as RU (Recurrent Users) in the results.

RESULTS

Volume of Activity in the Lobby and Variations

Error! Reference source not found. Figure 3 shows how the volume of people walking in the lobby, captured from Traces data logs, varies over a day. This is broken into three main types of day during our study:

- 1) A **closure day** in which the building was closed to visitors but could still be accessed to those with an electronic key-card (this covered 2 weeks during the middle of the study). It is possible to notice a higher volume of interactions around 9am, when summer employees arrive, and around lunchtime.
- 2) A **regular day** in which the number of detected people is generally higher than a closure day, particularly in the morning around 9am and around lunchtime. In these times employees and other people working in the space arrive and head to the offices (Figure 1 (e)), or go for lunch, often spending more time to linger in the lobby and explore Traces (Figure 1 (b-f)).
- 3) A day with an **exceptional event** where an event (meeting, conference) takes place in the building. A larger group of people (usually visitors) increases the volume of interactions, with a buffet in the lobby between 9-12pm, entering the stage room and exiting again around 3pm (Figure 3 and Figure 1 (c-d)).

How the flow of people varied over the day also impacted the visualisation and its readability. Whilst a low volume of people would result in clearer lines indicating where individuals walked, larger crowds would either create thick lines or overlapping traces that indicated increased activity, but made individual traces difficult to read (Figure 1 (c-d)).

Observed Modes of Engagement

From the video observation, we coded 1200 interaction instances. An interaction instance was defined every time a person walked on the area covered by Traces, or in close proximity (1-2m). We used the opportunistic interviews (and participant's video interactions) to act as initial codes. Users interacted with Traces in three main ways:

1) Active Engagement (AE) - 7% of observed instances

When users perform particular movements, or carry out specific behaviours with the primary intent to interact with the visualisation, e.g. walking around to test functions (Figure 1 (b)), or playfully to draw something (Figure 1 (f)).

2) Passive Engagement (PE) - 65% of observed instances

When users interrupt their current activity to observe the visualisation or others interacting with it, or pass by the lobby substantially gazing at the floor (Figure 1 (b)).

3) Implicit Interaction (II) - 28% of observed instances

When users walk on the visualisation without altering their walking trajectory by stopping or substantially gazing at the floor. This can happen, for example, when users are unaware of the system or ignore it (Figure 1 (a)).

Figure 4. Example illustrating passage between modes of engagement: a) S1 passes by observing the floor, b) S1 stops to observe others interacting. S2 engages directly while S3 observes, c) S2 and S3 step aside to discuss the installation and S1 joins the discussion (triangulation between spectators) d) S2 explains how the system works while S1 tries it (Spectator-Actor triangulation), e) S1 and S2 discuss together in Active Engagement (Actor-Actor triangulation), f) Follow Up Action: S1 steps aside to observe, while S2 continues to interact.

In the case a subject exited and re-entered the interaction area, it was counted as two interaction instances. If a participant passed 3 times on the visualisation, the first time interacting directly and the second and third ignoring it, that was counted as 1 instance of Active Engagement and 2 of Implicit Interaction. This video coding provides an understanding of the extent in which Traces redefined existing uses of the space by triggering active engagement.

Most interaction instances were of Passive Engagement (65%) in which people attended to, but did not interact with, the display. Either observing it (56%) or watching others interact with it (9%). Followed by 28% of Implicit Interaction instances. 7% of observed cases were Active Engagement, where people were trying to understand how Traces worked by walking in different ways, or drawing something specific (such as the heart in Figure 1 (f)). Individuals performed Active Engagement both while walking as individuals (2.5%), passing through in a group (3%), or in response to others already interacting (1.5%), where they moved from Passive Engagement to Active Engagement. Illustrating the Honeypot Effect [48], the majority of Active Engagement instances were triggered in the presence of others. Often discussions about the system were started with others nearby, accompanied by

demonstrations of the system's functions to others. We conclude that Traces did not disrupt the lobby function as a place of passage and waiting, but rather allowed users to engage and disengage 'on-the-go', as a natural part of walking through the space.

This demonstrates Traces' potential for social triangulation [43], supporting ice-breaking between co-present people, and sharing of knowledge about the system. In this respect triangulation was observed happening across engagement types [29]: between actors directly interacting, between spectators, and between actors and spectators (Figure 4).

Types of Use and Understanding

From the opportunistic interviews (OI) with visitors (we discuss recurrent users later), we identified three main categories of use and understanding of Traces: Social Awareness (18 of 27 users), Aesthetic (5 of 27) and Experimental (4 of 27).

Social Awareness

Most participants (18 of 27) considered Traces helpful to enhance their social awareness. The amount, order and intensity of the traces were easily coupled with others' walking trajectories, and triggered speculations about the behaviours and activities of different inhabitants passing through the lobby at different moments of the day:

"It interestingly tells something about the human behaviour and the thought that it is comfortable to choose the certain paths and walk certain ways. So moving around it is somehow soothing. It tells your certain route and certain path and places to go that tend to happen again and again" OI26

Participants considered Traces useful mainly to retrieve information related to the number of people at different times of the day, as well as their behaviour and habits, such as walking speed, directions, random walking, repetition of paths:

"once you come into the lobby and you do not see anyone, so you may think, 'Oh, this is silent today', but just before you came, it was full of people that are not there anymore. But with this, you can see the history that while there is no one here now, there has been a hell of a lot of people today" OI13

"Now there is a direct line that goes from the door to the lobby area, and then there are just some scattered points where people might be hanging around and passing by and standing a little while [...] some of them are just heading straight towards the coffee and the staff area" OI26

In these cases, engagement was mainly passive. Users often gazed while passing through, and sometimes slowed down or stopped for a better overview of the current state of the visualisation. Participants expressed curiosity towards others' activities in the space rather than towards already known system functionalities: *"I can see this as part of people's*

curiosity. It depends on the mood you are in, and what you have in mind. If you are in the perfect situation, maybe you have a spark, an idea" OI4

Despite the main passive use of Traces to retrieve social information, over half the participants (10 of 18) occasionally actively engaged to pass time while taking a break from work or waiting for friends in the lobby.

"First I did stay there and try to play with it, but after a couple of times I just walked through it when I realised what that did. Yes, but when we are in this lobby here, waiting for other people to come for lunch, I still do it sometimes" OI25.

Engagement modes were highly dependent on individual preferences, moods or situations.

Aesthetic Use and Understanding

Five participants (who visited the Design Factory less than 5 times since the activation of Traces) had not yet discovered its interactivity, and considered Traces solely as an artistic, non-interactive installation. Whilst they were unsure what Traces directly represented, it was clear that ideas of directions or paths were present. Despite the lack of awareness for the interactive elements, Traces was still considered an interesting installation, capturing attention and welcoming people into the atmosphere of the place:

"It's not normal to use plain light in the floor, when you're entering a room[...] it's like funny and curious, for example, sometimes I came in my own world, and it gets my attention, like, a way a path. But I'm not sure" OI5

This offered an excuse to start speaking with others (similar to Sacks' 'tickets to talk' to support ice-breaking between strangers [40] or Whyte's social triangulation [43])

Experimental Use

Four participants stated that they actively engaged, for example, by walking around to understand the mechanics of the system and what the visualisation meant. Of them, one only understood how the traces were generated after seeing other people passing by the lobby during the interview.

The findings validate and explain the modes of engagement already identified from video observations: the use of Traces for social awareness mainly implies Passive and Implicit modes of engagement, while experimental uses, characterised by Active Engagement, are sporadic (7%).

Evolution of Understanding and Use

Analysis of the discussion with recurrent users (RU) made it possible to understand how use, understanding and feelings towards the augmented Design Factory evolved during the study. Interviews were audio recorded, transcribed and coded to individuate how users understood Traces, how Traces affected their behaviours and activities, and general opinions about the installation in relation to the Design Factory over time. Three distinct phases of understanding and use emerged: 1) Experimental Phase, 2) Appropriation 3) Habituation.

Phase 1: Experimental Phase

During the second meeting, after the activation of Traces (about a week), only three of seven participants (RU1, RU3 and RU6) clearly understood that the visualisation represented real-time mobility patterns fading over time: *“I stopped and looked back, I was saying I know that this is my track now, and then I went to the machine shop, did something, and then I came back and I see more things going on [...] I liked the feeling that I realised that I can actually see people going. I’m not alone”* RU3

The other four participants (RU4, RU5, RU7 and RU8) had experienced Traces fewer times (less than 10). RU5 and RU8 considered it an artistic non-interactive work, while RU7 and RU4 considered there was a link to people and mobility in the visualisation. RU4 considered Traces to be a navigation system to direct users, whilst RU7 thought it was a heat map display showing the number of people present:

“it’s something like a heat map [...] [now] I can see there are three directions [...] There must be people going from here to there, like this guy who’s coming” RU7

Two factors influenced this variation in interpretation. Firstly, was the amount of attention users could devote to the visualisation when they had been passing through. Feedback was subtle, appearing in the periphery as individuals walked in the lobby. Secondly, during times with a high flow of people passing through, the visualisation became dense, making it harder to identify how user movement influenced it. However, all participants had some understanding of Traces, and how it worked became clear after the second interview. Interviews were conducted in the seating area nearby where Traces was installed, so participants could observe it, and notice people passing on it:

“I didn’t get the point because I arrived in the afternoon [when the lobby was busy]. I see now from this perspective how this thing works...people flow like this. And here people are standing” RU5

Once all participants understood that Traces was interactive, this engendered enhanced curiosity towards it, and led from Implicit to Active and Passive Engagement, with an aim to better understand how Traces worked. Exploration of the system response included walking tests, or subtler slowing down, stopping, turning, and observations of others and the visualisation at different times of the day:

“Because I’m here for work [...] I started noticing it, and every time I walk, I turn around and look, so that I can see my tracks. Sometimes I just walk on somebody else’s tracks, or try to. So, I start playing with it, anyway, nothing much. I didn’t have much time to kind of sit here and observe” RU7

The location of Traces, installed in the building lobby, which offered several different directions to reach locations in the building, increased curiosity not only towards directly interacting with it but also to consider and observe other’s activities:

“I want to see how it looks like early in the morning and then how it looks like late in the evening. If there had been many people going [...] so far it was a static thing” RU8

As with the video observations, in this phase conversations about Traces were often triggered between people present in the lobby (social triangulation [43]) and those engaging with the system. Participants described answering visitors’ questions about the system, or just conversing about Traces (technological facilitation [35]). Sometimes participants engaged in silent demonstration of Traces by walking in front of observers without starting a discussion, hoping for other’s attention to fall on their trace and provoke a conversation.

Phase 2: Appropriation

After the second discussion, all participants became aware that the visualization displayed mobility patterns of people passing by. During the third and fourth interview (about 2 and 4 weeks after Traces’ activation) all were already very familiar with traces (reporting to have interacted with it more than 40 times), noticing and exploring possible uses. In this phase participants experienced a shift in attention from Active Engagement (by exploring and directly interacting with Traces), to Passive Engagement. They started to mainly observe the actions of others using Traces, reflecting on these, and extracting personal meaning from the visualisation.

This supported the appropriation of Traces to more subjective use in relation to personal activities in the Design Factory. Participants developed daily routines that incorporated Traces to help support wider consideration of the space. For example, RU1 (who usually entered the building via a rear door away from the installation) started to enter from the front door to gain an overview of how many people were already in the building, and try to guess who they might be:

“Last week I used this other door just to see how many people had come here before me. One day only two...I was so happy! I think it was at least [name redacted], she’s quite early here, and probably [name redacted]” RU1

RU3, RU5 and RU6 found themselves paying more attention to people passing through the lobby, sometimes guessing who through interpreting Traces:

“it’s like spying on people in a way, following people’s tracks. You also realise that other people can spy on you...It’s more anonymous in a way[...] you also kind of read the environment already, and if you know that you have seen these faces, you can try to guess which of them was the one going there” RU3

RU7, RU4, and RU8 found ways to integrate Traces into their working day, using it as a way of improving perceived productivity. P7, for example, used Traces as a motivation to take breaks from his desk. Walking to “play” with Traces, such as redrawing lines that were fading away by walking over them:

“It’s good distraction you know. You were working so long and then you just passed by and see: ‘Oh, I’m making this pattern now’ so you’re just away for that moment from your work, and then once again you’re back in the thing. So kind of a small mind break, a playful moment in between” RU7

RU4 and RU8 found the presence of others in the building (observed from Traces) motivated their working times. Using the presence of others as a motivation, whilst using the lower volume of traces in the evening as a motivation to go home. RU5 and RU6 also recognised such use in the observation of others, noting how Traces supported short moments of stress relief, distraction and entertainment, as well as triggering interaction between people:

“I saw today that [a girl] was trying to cover everything with the steps and that is really interesting. I think people are spending more time there and usually people weren’t so active in that area [...] people are not paying attention obviously when they’re in a hurry[but] if they’re waiting for someone they start spending time here just walking around and trying to see how it works while the other person is coming” RU6.

Appropriation is illustrated through the drop of Active Engagement (i.e. direct exploration of system features when still novel) for more Implicit and Passive Interactions (such as observing the visualisation to retrieve information about other inhabitants), and the formation of more personal uses and understandings.

Phase 3: Habituation

In the last meeting participants reported considering more deeply how Traces reflected what was happening in the Design Factory. They got used (habituated) to the system, personal uses solidified and Active Engagement was completely abandoned for even lighter forms of Passive Engagement.

Participants could construct relationships between the state of Traces and contextual aspects of the Design Factory simply by scanning the visualisation as they walked through the space, rather than needing to stop, observe and consider it (as was the case in the Appropriation phase). Conscious implicit interaction also happened more often as participants had an expectation of what the visualisation would show when they arrived, or at different points of the day. Attention was grabbed if Traces varied significantly from this expectation.

Habituation is clear in this consideration of Traces as an ambient information layer, or a sort of embedded newspaper that could be browsed to identify any particularly interesting stories:

“I look at it like I look at a magazine every day because I know there’s news and then you’re just watching through, are they interesting or not. It’s a force of habit in a way [...] I’ve grown to understand how it works, [it] gives me a lot more information I believe than for a person that doesn’t know it at all.” RU3

Traces did not dramatically change the way participants used the space, but supported context related thoughts about others in the space and their activities, and from these, derived relations with the Design Factory. For example, artistic interactions with Traces may indicate new people or visitors trying to understand how it worked. Dense traces leading to the event space might indicate an event happening that the viewer was previously unaware of. This was a marked change in how participants used Traces. For example, RU7 shifted his behaviours from more playful interactions (in which he would have drawn a line every time he saw the other fading) to more passive ways of relaxing and making use of the information, appropriating its use beyond novelty:

“You figure out what’s going on very easily. I see people flow and how the patterns are formed. So it gives the awareness and a kind of moment to stop by [...] if you’re working it gives you a stress buster” RU7

Participants spent less time observing how others interacted with Traces, and paid more attention to how the visual representation related to social happenings. A clear example of this occurred during the period the Design Factory was ‘closed’ (when key card holders could enter, visitors could not, and no external events took place). Traces was still active during this time, and the change was clearly visible to participants. This informed understanding of the use of the Design Factory during this time in sometimes-unexpected ways. RU3 for example noticed some days where there were more people than previous days even though the building was still closed, probably because some of the staff were back from vacations:

“Now we’re still closed but it still looks pretty normal, not as cluttered as usual when the Design factory was open, but still I can conclude that there’s people here for sure.[...] For example yesterday was a pretty quiet day because half of the staff was in vacation, and you could clearly tell the difference” RU3

When the Design Factory reopened to the public, participants immediately noticed the change in Traces:

“it was more like a haphazard way of spots everywhere. I was surprised in a way, like I thought it’s evening time so there should be anyone still it showed some light signals, like there were people here...definitely it looks different when Design Factory is very active and when it’s not active....maybe the Korean delegation” RU4.

In particular, a large group of visitors attended events in the event space and other nearby rooms (see exceptional day in Figure 1 (c-d)). That evening, RU4 and RU6 were surprised to see high density of traces in contrast to those shown when the building was ‘closed’.

DISCUSSION

Our 6 week study allowed us to uncover rich practices of how individuals used and interpreted Traces beyond novelty

effects. We discuss these, starting from our research questions, and outline the broader relevance of our findings.

RQ1: What is the impact of a visualisation of low-level walking trajectories on supporting social awareness in a public building? Traces supported different levels of social awareness and interaction, related to users' familiarity with the system and the space. Interpretation and use of Traces largely depended on a participant's ability to interpret the visualisation in relation to contextual clues, familiarity with the space, the amount of time spent in the lobby, and allocation of attention (e.g. how attention was affected by being in a hurry, or cognitively engaged in other tasks). New users appreciated the aesthetic, welcoming aspect of Traces and enjoyed discovering interaction. While more experienced users appropriated it as an ambient information-layer for social awareness. It was easy to deduce if individuals were walking straight to offices, lingering in the lobby, were new visitors to the building, or if events were taking place. While previous research shows the benefit of locally embedded visualisations [41], and ambiguous information to support personal interpretation about behaviours [44], we present the potential for low-level behavioural information to convey higher-level meaning when displayed *in-situ*.

The open use and interpretability of Traces allowed multiple attitudes towards it to co-exist, facilitated interaction between people (conversation [40] and social triangulation [43]), and with it collaborative sense-making and appropriation. Experienced users assumed the role of facilitators [35], helping others to understand the system by answering questions or engaging in discussion and demonstration. In this respect, not only was social awareness enhanced, but also social connection and feelings of belonging to a community. While public interactive displays are usually designed to deliver specific information, we present the benefits of designing for more open uses and interpretation, allowing users to make sense in both collaborative and subjectively meaningful ways.

RQ2: Does the reactive floor projection reflect existing uses of the space or significantly redefine them? Reactive feedback allowed individuals to interact without needing to alter their existing behaviour (implicit engagement). The situated glanceable visualisation also allowed participants to interpret content simply by glimpsing the floor while walking through (passive engagement). Basing interaction on implicit and passive modes of engagement allowed most interactions to be congruent with common practices of individuals in the space, as users did not need to perform any special interactions in order to generate and access information. In this way Traces largely reflected existing practices in the building, rather than radically redefining its use (such as with other publicly embedded displays [9]). This allowed individuals to understand what was going on in the building by interpreting Traces through their existing familiarity with the space. For example, experienced users were able to identify if new users or visitors were in the building by

identifying the more playful interactions these users engaged in.

Whilst the design and research of public technologies largely focuses on active engagement (e.g. [9,29,42]), we identified how implicit interaction could be leveraged to engage users, whilst preserving existing public behaviours. Feedback in response to everyday behaviours removed the need to specifically devote time to learn how to interact. Rather, understanding emerged naturally over time. Implicit and passive interactions could be employed to reduce barriers to interaction with public systems, such as social apprehension (i.e. not knowing how to interact [37] or what content to create [19]). Reactive feedback and content generation could be employed to preserve pedestrian flow, (e.g. in areas such as stations and public squares), whilst still allowing a useful interaction with a public display.

RQ3: How does understanding and use evolve over time and differ between recurrent and non-recurrent users?

By studying how use evolved over time, we identified how recurrent users could appropriate Traces through 3 distinct phases. The rich ways in which users interpreted and appropriated Traces into their daily routines contrast how more specific displays of activity suffer from display blindness if not needed [18,28,38]. Individuals could create meaning that was important to them: i.e. whether any event happened, if they should leave for the day, if they were the first person to arrive, or if a colleague had arrived. Individuals invested value in the display. Beyond this, recurrent users became habituated to Traces, fixing its role as a social information layer that could be easily browsed while passing by. Participants had an expectation of how the visualisation should be, and altered their engagement if it was different (e.g. if an unknown event was taking place).

Appropriation of Traces as a social-information-layer also relates to the importance of implicit and passive interaction. Recurrent users stopped active engagement after about 2-3 weeks of personal use (as its novelty effect wore off). Yet responsive content generation and at-a-glance access (implicit/passive interaction) still allowed users to engage and develop personal uses for Traces. As most interactions were implicit and passive, non-recurrent user's active experimentation of Traces did not disrupt the uses recurrent users had developed. Rather, they acted as signals to recurrent users that there are new people in the building who are trying to understand how Traces works. While existing work has mainly focused on active engagement, we argue there is significant value in studying the relations between mixed-modes of engagement and situated social interaction.

DESIGN CONSIDERATIONS

Our study contributes more widely to how public interactive displays can support sociality over time. From awareness about others' presence and activities, to face-to-face interaction and feelings of belonging to a community. We outline a set of design considerations that should be considered by future designers seeking to support social

awareness. Table 1 outlines in detail the core contributions which should be considered alongside these design considerations.

Contribution	Key Points
An understanding of how a Reactive Floor projection can support social awareness	<ul style="list-style-type: none"> • Ambiguity supports open interpretation and appropriation • Many uses are related to sociality • Traces reflected, but did not change, the primary purpose of the space
An understanding of how use evolves over time and experience	<ul style="list-style-type: none"> • Understanding evolves through three phases • Only a minority of interactions are active • Behavioural and Reactive feedback are important to support continued use. • Ambiguity supports concurrent interaction at different levels of understanding.
A method to effectively study how the impact of an installation on social awareness can be studied	<ul style="list-style-type: none"> • Monitor the overall social activity independently (logging) • Study how understanding evolves • Sample through the study • Triangulate between data pools to deepen understanding

Table 1: An overview of the key contributions of the Traces study with highlighted key points.

Behavior mirroring and ambiguity lowers barriers to interaction: Providing ambiguity in what the visualization means, yet making it clear what happens where a user steps on it, reduces the risk of embarrassment from not understanding how to use it. Whilst users can get immediate value, the repeated nature of use means understanding can evolve over time, potentially provoking social interactions and collaboration.

Supporting multiple modes of engagement is important for long term sustainability: Flexible modes of engagement are important. They both support users to interact based on individual's desire and availability to interact. Only a minority of interactions were active, with explicit intent to interact with Traces. Yet the value for our recurrent group was through observation of interactions with others. Without flexible interaction modes, the value of Traces would have been lost.

Low-level behaviour mirroring supports higher level interpretation: Although behaviour mirroring presented only low-level information, its *in-situ* presentation allowed rich interpretation on its meaning. It also supports users' social awareness, feeling of embodiment and belonging to a community. It also encourages understanding to arise from exploration and collaboration. This can support dynamic appropriation and social interaction.

Consider how to support users with different levels of understanding concurrently: Open use and interpretation of Traces allowed users with different levels of exposure and regularity of exposure (workers vs one-time visitors) to concurrently use Traces together. Habituated behaviours were not disrupted by new users.

LIMITATIONS AND FUTURE WORK

Traces provided a platform for different types of users to better understand the activities of others in the building. Our future work is focused on enhancing the visualisation to both increase the data shown and its clarity (particularly during high volume traffic periods). Although we projected in a relatively small area, this provided significant insight, and we hope to expand this by employing a larger area. Whilst the Design Factory represents a creative and open space that is a good 'first step' to investigate, it cannot be argued to represent all spaces where an approach such as Traces may be useful. By replicating our work in places with varying characteristics and diversity of occupants, we can identify commonalities in our findings, and tease out the impact of the environment.

CONCLUSIONS

Our study of Traces has explored how social awareness and feelings of connection within a community can be enhanced by *in-situ* visualisation of low-level human activity. By supporting multiple different ways to interact, use of Traces was sustained over the study. This allowed rich appropriation, but without the display dominating the main use of the space. Traces allowed individuals to explore activities and social practices of the Design Factory, and appropriate a range of personal uses from relatively basic data. These, enhancing curiosity and engaging a connection with the lived environment and others in it.

ACKNOWLEDGEMENTS

We thank the staff of the Design Factory and all of our participants for their contributions to this work.

REFERENCES

1. Mary Barreto, Evangelos Karapanos, and Nuno Nunes. 2013. Why don't families get along with eco-feedback technologies? *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI (CHIItaly '13)*, ACM, 1–4. <http://doi.org/10.1145/2499149.2499164>
2. Steve Benford, Andy Crabtree, Martin Flintham, et al. 2011. Creating the Spectacle: Designing Interactional Trajectories through Spectator Interfaces. *ACM Transactions on Computer-Human Interaction* 18, 3: 1–28. <http://doi.org/10.1145/1993060.1993061>

3. Steve Benford, Gabriella Giannachi, Boriana Koleva, and Tom Rodden. 2009. From interaction to trajectories: Designing Coherent Journeys Through User Experiences. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09)*, ACM, 709–718. <http://doi.org/10.1145/1518701.1518812>
4. Mark Bilandzic, Ronald Schroeter, and Marcus Foth. 2013. Gelatine: making coworking places gel for better collaboration and social learning. *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration (OzCHI '13)*, ACM, 427–436. <http://doi.org/10.1145/2541016.2541027>
5. Daniel Carter. 2014. Encouraging Ambiguous Experience : Guides for Personal Meaning Making. *Proceedings of the 2014 companion publication on Designing interactive systems (DIS Companion '14)*, ACM, 61–64. <http://doi.org/10.1145/2598784.2602782>
6. Luigina Ciolfi, Mikael Fernström, and Liam J Bannon. 2007. The Shannon Portal Installation: An Example of Interaction Design for Public Places. *IEEE Computer Society* 40, 7: 65–72. <http://doi.org/10.1109/MC.2007.255>
7. Paul Dourish. 2003. The appropriation of interactive technologies: Some lessons from placeless documents. *Computer Supported Cooperative Work (CSCW'03)* 12, 4: 465–490. <http://doi.org/10.1023/A:1026149119426>
8. Sebastian Draxler, Gunnar Stevens, Martin Stein, Alexander Boden, and David Randall. 2012. Supporting the Social Context of Technology Appropriation: On a Synthesis of Sharing Tools and Tool Knowledge. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'12)*, ACM, 2835–2844. <http://doi.org/10.1145/2207676.2208687>
9. Ava Fatah gen. Schieck, Vasillis Kostakos, and Alan Penn. 2009. Exploring Digital Encounters in the Public Arena. In Struppek M. Willis K., Roussos G., Chorianopoulos K. (ed.). Springer, London. http://doi.org/10.1007/978-1-84882-727-1_9
10. Patrick Tobias Fischer, Christian Zöllner, Thilo Hoffmann, Sebastian Piatza, and Eva Hornecker. 2013. Beyond information and utility: Transforming public spaces with media facades. *IEEE Computer Graphics and Applications* 33, 2: 38–46. <http://doi.org/10.1109/MCG.2012.126>
11. Lyndsey Fisk, Marcus Carter, Behnaz Rostami Yeganeh, Frank Vetere, and Bernd Ploderer. 2014. Implicit and Explicit Interactions in Video Mediated Collaboration. *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: the Future of Design (OzCHI '14)*, ACM, 250–259. <http://doi.org/10.1145/2686612.2686650>
12. Myriam Fréjus. 2015. Taking into Account User Appropriation and Development to Design Energy. *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15)*, ACM, 2193–2198. <http://doi.org/10.1145/2702613.2732718>
13. Dominic Furniss, Ann Blandford, and Paul Curzon. 2011. Confessions from a grounded theory PhD: experiences and lessons learnt. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*, ACM, 113–122. <http://doi.org/10.1145/1978942.1978960>
14. Sarah Gallacher, Jenny O'Connor, Jon Bird, et al. 2015. Mood Squeezer : Lightening up the Workplace through Playful and Lightweight Interactions. *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing (CSCW '15)*, ACM, 891–902. <http://doi.org/10.1145/2675133.2675170>
15. William W. Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity as a resource for design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*, ACM, 233–240. <http://doi.org/10.1145/642611.642653>
16. Erving Goffman. 1963. *Behavior in public places: notes on the social organization of gatherings*. The Free Press, New York, NY, USA.
17. Steven Houben and Christian Weichel. 2013. Overcoming interaction blindness through curiosity objects. *CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13)*, ACM, 1539–1544. <http://doi.org/10.1145/2468356.2468631>
18. Elaine M. Huang, Anna Koster, and Jan Borchers. 2008. Overcoming assumptions and uncovering practices: When does the public really look at public displays? *Proceedings of the 6th International Conference on Pervasive Computing (Pervasive '08)*, Springer-Verlag, 228–243. http://doi.org/10.1007/978-3-540-79576-6_14
19. Clinton Jorge, Julian Hanna, Valentina Nisi, Nuno Nunes, Miguel Caldeira, and Giovanni Innella. 2013. Fostering ambiguity: Decontextualizing and Repurposing a Familiar Public Display. *Proceedings of the Biannual Conference of the Italian Chapter of SIGCHI (CHIItaly '13)*, ACM, 10. <http://doi.org/10.1145/2499149.2499166>
20. Bradley S. Jorgensen and Richard C. Stedman. 2001. Sense of Place As an Attitude: Lakeshore Owners Attitudes Toward Their Properties. *Journal of Environmental Psychology* 21: 233–248. <http://doi.org/10.1006/jevp.2001.0226>
21. Rui José, Nuno Otero, and Jorge C.S. Cardoso. 2014. Dimensions of Situatedness for Digital Public Displays. *Advances in Human-Computer Interaction*, Article 16 (January 2015). <http://doi.org/10.1155/2014/474652>

22. Evangelos Karapanos, Marc Hassenzahl, and Jean-Bernard Martens. 2008. User experience over time. *CHI '08 Extended Abstracts on Human Factors in Computing Systems (CHI EA '08)*, ACM, 3561–3566. <http://doi.org/10.1145/1358628.1358891>
23. Kai Kuikkaniemi, Giulio Jacucci, Marko Turpeinen, Eve Hoggan, and Jörg Müller. 2011. From space to stage: How interactive screens will change urban life. *Computer* 44, 6: 40–47. <http://doi.org/10.1109/MC.2011.135>
24. Rod McCall, Shaleph O'Neill, Fiona Carroll, David Benyon, and Michael Smyth. 2005. Responsive environments, place and presence. *PsychNology Journal* 3, 1: 35–73.
25. Joseph F. McCarthy, David W McDonald, Suzanne Soroczak, David H Nguyen, and Al Mamunur Rashid. 2004. Augmenting the Social Space of an Academic Conference. *Augmenting the social space of an academic conference. In Proceedings of the 2004 ACM conference on Computer supported cooperative work (CSCW '04)*, ACM, 39–48. <http://doi.org/10.1145/1031607.1031615>
26. Joseph F McCarthy, Shelly D Farnham, Yogi Patel, et al. 2009. Supporting Community in Third Places with Situated Social Software. *Proceedings of the fourth international conference on Communities and technologies (C&T '09)*, ACM, 225–234. <http://doi.org/10.1145/1556460.1556493>
27. David K. McGookin, Stephen A. Brewster, and Georgi Christov. 2014. Studying Digital Graffiti as a Location-Based Social Network. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*, ACM, 3269–3278. <http://doi.org/10.1145/2556288.2557266>
28. Nemanja Memarovic, Sarah Clinch, and Florian Alt. 2015. Understanding Display Blindness in Future Display Deployments. *Proceedings of the 4th International Symposium on Pervasive Displays (PerDis '15)*, ACM, 7–14. <http://doi.org/10.1145/2757710.2757719>
29. Nemanja Memarovic, Marc Langheinrich, Florian Alt, Ivan Elhart, Simo Hosio, and Elisa Rubegni. 2012. Using public displays to stimulate passive engagement, active engagement, and discovery in public spaces. *Proceedings of the 4th Media Architecture Biennale Conference on Participation (MAB '12)*, 55–64. <http://doi.org/10.1145/2421076.2421086>
30. Daniel Michelis and Jörg Müller. 2011. The Audience Funnel: Observations of Gesture Based Interaction With Multiple Large Displays in a City Center. *International Journal of Human-Computer Interaction* 27, 6: 562–579. <http://doi.org/10.1080/10447318.2011.555299>
31. Jörg Müller, Dennis Wilmsmann, Juliane Exeler, et al. 2009. Display blindness: The effect of expectations on attention towards digital signage. *International Conference on Pervasive Computing*, Springer, 1–8. http://doi.org/10.1007/978-3-642-01516-8_1
32. Michael Muller, Katja Neureiter, Alina Krischkowsky, and Manfred Tscheligi. 2016. Collaborative Appropriation: How Couples, Teams, Groups and Communities Adapt and Adopt Technologies. *Proceedings of the 19th ACM Conference on Computer Supported Cooperative Work and Social Computing Companion (CSCW '16 Companion)*, 473–480. <http://doi.org/10.1145/2818052.2855508>
33. Sean A. Munson, Emily Rosengren, and Paul Resnick. 2011. Thanks and tweets: comparing two public displays. *Proceedings of the ACM 2011 conference on Computer supported cooperative work (CSCW '11)*, ACM, 331–340. <http://doi.org/10.1145/1958824.1958875>
34. Gonzalo Parra, Joris Klerkx, and Erik Duval. 2014. Understanding Engagement with Interactive Public Displays. *Proceedings of The International Symposium on Pervasive Displays (PerDis '14)*, ACM, 180–185. <http://doi.org/10.1145/2611009.2611020>
35. Pablo-Alejandro Quinones. 2014. Cultivating practice & shepherding technology use: supporting appropriation among unanticipated users. *Proceedings of the 17th ACM conference on Computer supported cooperative work & social computing (CSCW '14)*, ACM, 305–318. <http://doi.org/10.1145/2531602.2531698>
36. Jane Ritchie, Liz Spencer, A. Michael Huberman, and Matthew B. Miles. 2011. Qualitative Data Analysis for Applied Policy Research. In *The Qualitative Researcher's Companion*, A. Michael Huberman and Matthew B. Miles (eds.). SAGE Publications, Thousand Oaks, 305–329. <http://doi.org/10.4135/9781412986274.n12>
37. Yvonne Rogers, Jon Bird, Lisa Koeman, and Vaiva Kalnikait. 2014. What Chalk and Tape Can Tell Us : Lessons Learnt for Next Generation Urban Displays. *Proceedings of The International Symposium on Pervasive Displays (PerDis '14)*, ACM, 130–135.
38. Yvonne Rogers, William R Hazlewood, Paul Marshall, Nick Dalton, and Susanna Hertrich. 2010. Ambient Influence: Can Twinkly Lights Lure and Abstract Representations Trigger Behavioral Change? *Proceedings of the 12th ACM international conference on Ubiquitous computing (UbiComp '10)*, ACM, 261–270. <http://doi.org/10.1145/1864349.1864372>
39. Enrico Rukzio, Michael Müller, and Robert Hardy. 2009. Design, Implementation and Evaluation of a Novel Public Display for Pedestrian Navigation: The Rotating Compass. *Proceedings of the 27th International Conference on Human Factors in Computing Systems (CHI '09)*, ACM, 113–122. <http://doi.org/10.1145/1518701.1518722>

40. Harvey Sacks. 1992. *Lectures on Conversation*. Blackwell Publishing.
41. Alex S. Taylor, Siân Lindley, Tim Regan, and David Sweeney. 2015. Data-in-Place: Thinking through the Relations Between Data and Community. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*, ACM, 2863–2872. <http://doi.org/10.1145/2702123.2702558>
42. Daniel Vogel and Ravin Balakrishnan. 2004. Interactive Public Ambient Displays: Transitioning from Implicit to Explicit, Public to Personal, Interaction with Multiple Users. *Proceedings of the 17th annual ACM symposium on User interface software and technology (UIST '04)*, ACM, 137–146. <http://doi.org/10.1145/1029632.1029656>
43. William Hollingsworth Whyte. 2001. *The Social Life of Small Urban Spaces*. Project for Public Spaces.
44. Julie R. Williamson and Stephen Brewster. 2014. Capturing performative actions for interaction and social awareness. In *Mobile Social Signal Processing (MSSP 2010)*. Springer, Berlin, Heidelberg, 51–63. http://doi.org/10.1007/978-3-642-54325-8_6
45. Julie R. Williamson and Daniel Sundén. 2015. Enter the Circle - Blending Spherical Displays and Playful Embedded Interaction in Public Spaces. *PerDis '15*, 195–200.
46. Julie R. Williamson and John Williamson. 2014. Analysing Pedestrian Traffic Around Public Displays. In *Proceedings of The International Symposium on Pervasive Displays (PerDis '14)*, ACM, 13. <http://doi.org/10.1145/2611009.2611022>
47. Christian Winkler, Julian Seifert, David Dobbstein, and Enrico Rukzio. 2014. Pervasive information through constant personal projection: the ambient mobile pervasive display (AMP-D). *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*, ACM, 4117–4126. <http://doi.org/10.1145/2556288.2557365>
48. Niels Wouters, John Downs, Mitchell Harrop, et al. 2016. Uncovering the Honeypot Effect: How Audiences Engage with Public Interactive Systems. *Proceedings of the 2016 ACM Conference on Designing Interactive Systems (DIS '16)*, ACM, 5–16. <http://doi.org/10.1145/2901790.2901796>
49. Niels Wouters, Jonathan Huyghe, and Andrew Vande Moere. 2014. StreetTalk: participative design of situated public displays for urban neighborhood interaction. *Proceedings of the 8th Nordic Conference on Human-Computer Interaction Fun, Fast, Foundational - NordiCHI '14*, ACM, 747–756. <http://doi.org/10.1145/2639189.2641211>