Does the Public Still Look at Public Displays? A Field Observation of Public Displays in the Wild

CALLUM PARKER, The University of Sydney, Australia
MARTIN TOMITSCH, The University of Sydney, Australia
JUDY KAY, The University of Sydney, Australia

Public displays are widely used for displaying information in public space, such as shopping centres. They are typically programmed to display advertisements or general information about the space in which they are situated. Due to recent advances in technology, public displays are becoming ubiquitous in space around cities and can potentially enable new interactions with public space. However, despite these advances, research reports that public displays are often found to be: (1) generally irrelevant to the space in which they are situated; and (2) ignored by passers-by. Although much research has focused on tackling these issues, a gap remains regarding knowledge about how public displays in the wild are currently being used at a time when people are increasingly relying on their smartphones as a main source for accessing information and for connecting with others. The study reported in this article aims to address this gap by presenting new insights about the current practices of non-research public displays and their role in a hyperconnected society. To achieve this, we provide results from a field observation study of non-research public displays and contextualise our findings within an analysis of related work. This article makes three main contributions: (1) identifying how user engagement with public displays has changed over the past 10 years; (2) understanding how the pervasiveness of smartphones and other connected devices has modified whether users notice public displays and their interactions with public displays; and (3) outlining design recommendations and opportunities towards making public displays more relevant in a hyperconnected society.

CCS Concepts: • **Human-centered computing → Field studies**;

Additional Key Words and Phrases: Public Displays, Design, Field Observation, Hyperconnected society

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1 INTRODUCTION

A public display is a medium that brings digital content into the real world and into the eyes of the general public. With smaller hardware form factors and lower costs in display technology there is a growing investment into public displays, spawning large commercial public display networks, such as the Media Poles in Gangnam, Seoul [30] and Live Touch Screens in Sydney, Australia [48]. There has also been significant investment into digital out of home (DOOH) advertising, due to a strong growth of this format over analogue advertisements and this

Authors' addresses: Callum Parker, The University of Sydney, Sydney School of Architecture, Design and Planning, Sydney, NSW, 2006, Australia, callum.parker@sydney.edu.au; Martin Tomitsch, The University of Sydney, Sydney School of Architecture, Design and Planning, Sydney, NSW, 2006, Australia, martin.tomitsch@sydney.edu.au; Judy Kay, The University of Sydney, Sydney School of Architecture, Design and Planning, Sydney, NSW, 2006, Australia, judy.kay@sydney.edu.au.

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investment is predicted to increase until the year 2020 [47]. In research, there is a growing body of work studying public displays for purposes other than simply advertising. For instance, previous work has demonstrated that public displays can help engage local communities, allowing people to submit and publicly display their opinions on civic topics [26, 50, 60]. Other work showed that public displays can be used to augment existing services, such as bus timetables [42], community noticeboards [4], and wayfinding signage [16].

Despite this growth and potential of public displays as a ubiquitous media platform, a remaining challenge is getting people to notice and interact with the content on these displays [5, 17, 33, 43]. Research has focused on addressing this challenge by designing public displays to grab users' attention through implicit responsiveness to passers-by [2, 37, 56] and playful interactions [52], allowing for the honeypot effect to occur [13, 35, 59]. While capturing attention is an important factor for engagement with public displays, the relevance of the content shown on a public display is also important. Content that is relevant to the space or community in which the public display is situated [4, 20, 26] and to an individual's activities [41] can be effective at successfully engaging users.

Although there is much value in testing public displays in research, they are not always representative of non-research public displays deployed in the wild [5]. To overcome common assumptions made about non-research displays, Huang et al. [29] carried out an observation study in 2008, which led to a better understanding of non-research public displays in the wild. Their findings suggested that to increase attention, public displays should be positioned at eye-level and the content should be designed with the setting and audience taken into account. Since this work was published however, society and public space has changed. The changes in society have occurred largely in part due to new technological trends since the release of Apple's first-generation iPhone in 2007 [55], leading to a rise of connected personal devices, such as smartphones, tablets, and smart watches. The adoption of smart personal devices and their integration into people's lives allows people to be hyperconnected at all times [45], where information is readily available from personal devices. This ubiquitous information access raises new contemporary questions about the role of public displays.

In this paper, our aim is to offer researchers and designers concrete, ecologically valid knowledge about the use of non-research public displays in the wild by revisiting Huang et al.'s [29] study conducted 10 years ago. To achieve this, we report findings from a field observation study of 18 non-research public displays carried out across 8 different locations in Sydney, Australia, to understand current trends and observe people's behaviour around public displays.

The study itself is driven by four research questions in relation to public displays. More specifically, we were interested in the effect of four aspects on users' engagement with public displays, that is, whether users noticed and looked at the public display and (for interactive public displays) whether users interacted with the display. The research questions, therefore, are as follows:

- (RQ1) What design elements attract attention/convey interactivity?
- (RQ2) What is the effect of position and location?
- (RQ3) What type of content is relevant?
- (RQ4) What is the effect of smartphones?

Our study contributes to knowledge of public displays and ubiquitous computing research in three ways. First, the findings from our study contribute to an understanding of how current technological trends, such as smartphone usage, have modified user engagement with public displays. Second, we identify how public displays and user engagement with them has changed since the study conducted by Huang et al. [29] 10 years ago by contrasting the findings from our study with theirs. Finally, we outline design recommendations towards improving user engagement with public displays.

2 BACKGROUND

To support and ground our study, we first review literature that has investigated the role of size, positioning, and responsiveness of public displays for attracting attention and conveying interactivity (RQ1 and RQ2). We then discuss methods to make public displays relevant (RQ3), such as changing content based on context, related to people and the environment in which the public display is situated. Next we discuss the increase of personal device usage in society, which we refer to as hyperconnectedness, and how this has affected the way we use a public space and public technologies within it. This feeds into RQ4 as it can have a potential effect on public display usage. Finally, we summarise this work and discuss how it influenced our study.

2.1 Gaining Attention and Conveying Interactivity

The problem of public displays gaining attention is referred to in public display literature as "*display blindness*" [29, 33, 38]. Display blindness is similar to the concept of banner blindness on the web. It is characterised as either passers-by ignoring the existence of public displays as they assume the content is not of relevance or public displays becoming lost in the background of other things in the space vying for attention.

To tackle this, much research has aimed at understanding display blindness and how it can be overcome. Huang et al.'s [29] study of non-research public displays in the wild found that attention to public displays can be affected by the following factors:

- **Brevity of glances.** People only pay brief attention to public displays.
- **Position.** Public displays positioned at eye-level attract more attention than those that are not.
- **Content format.** Dynamic content, like videos, tend to attract more attention than static content.
- **Catching the eye.** Permeability and items within the space positioned nearby a public display can help draw attention and bring the public display into the peripheral vision of passers-by.
- **The "captive" audience.** Describes people held captive nearby a public display, such as on an escalator or waiting in line.
- **Small displays vs. large displays.** Smaller displays are generally better at sustaining longer amounts of attention than larger displays, as the smaller displays are designed for more intimate use, whereas large displays are more exposed.

While their study highlighted the effect positioning has on user engagement, Dalton et al. [17] found that people may notice public displays regardless of where they are positioned. In their study, participants' eyes were tracked using Tobii Mobile Eye Tracking Glasses to determine what they were gazing at while they moved through a shopping centre. Findings from this study suggest that display blindness may not always occur, as participants gave short glances to most of the public displays. As acknowledged by the authors, however, the study focused on one shopping centre only. The requirement for participants to wear a head-tracking device may have had a further effect on the results and their ecological validity. Our study adds to this work by including public displays positioned in multiple contexts and observing people without requiring them to wear any measurement instruments.

Research studies of public interactive displays report that adding interactivity is an effective method for garnering and retaining attention [54]. Interactivity on large screens can be eye-catching when the public display responds to passers-by, for example, through screen elements that react to people's presence and proximity [25, 37]. In some cases, someone interacting with a public display can trigger a social phenomenon known as the Honeypot effect [13, 35, 59]. This effect can occur when a passer-by notices someone interacting with a public display, potentially leading them to approach the public display and interact themselves.

However, making public displays interactive leads into the challenge of conveying that the public display is interactive [22]. To overcome this challenge, previous research has investigated the effectiveness of public display interfaces that react to the presence of passers-by. Ackad et al. [2] reported on a study of a large interactive information display that used a Microsoft Kinect sensor with Mid-air gestures as a form of input. Their findings showed that interface elements are more likely to gain attention if they follow passers-by. In similar work, Beyer et al. [11] deployed a long display in a public space and observed passer-by behaviour. Their study concluded that visual stimuli that follow the passers-by, such as frames and ellipses, are effective at grabbing the attention of passers-by and directing them into position for interaction.

This previous work shows that making public displays interactive and responsive can increase the chance of a public display being noticed and used. In this study, we observe how effective public displays are at gaining attention and in the case of PIDs, convey to passers-by that they are interactive. Importantly, our study focuses on non-research public displays, whereas most of the previous work in this area has investigated public displays within the context of a research deployment study, that is, public displays that were designed and deployed by the researchers for the purpose of conducting a user evaluation study. As such, our work is closer aligned with and adds to the studies conducted by Huang et al. [29] and Dalton et al. [17].

2.2 Making Content Relevant

While making public displays eye-catching is important, the actual or perceived relevance of the display's content can be another factor that influences user engagement. Research identified that one of the reasons people do not interact or look at a public display is due to their perception that content on a public display is irrelevant [14, 20, 41]. This problem can potentially be overcome when the content is related to the context of the space or community. For instance, Alt et al. [4] showed that content related to events and local information was highly relevant when they studied a digital noticeboard display that allowed citizens to post and view user-generated content, such as classified advertisements from citizens trying to sell second hand goods or promote community events. Other work used public displays to engage citizens on local issues for members of the community to voice their concerns and see aggregated data about what the other people in the community think about particular issues [8, 26, 50, 51].

Content on a public display can be tailored further through user profiles, similar to the ones commonly found on the web [34]. However, logging into a public display the same way as one would log into a web service on a personal computer is not very practical and could raise privacy implications. As a potential solution, research has suggested a device-based approach where personal devices are used as a private method of identification [44]. Early work [19] utilised Bluetooth device names, where users could change their device's name to a search query triggering public displays they walked past to display certain content. Other work [20, 41] tested custom apps that allowed the user to set their own preferences for the type of content they would like to see and would send this information over WiFi to personalise nearby public displays. At the same time, personalisation of public displays needs to be carefully tailored to ensure users perceive the information as useful [41], such as making the content relevant to what users are currently doing, like displaying traffic conditions or weather when the user is travelling home from work. However, a device-based approach assumes that everyone has a personal device and that they would spend the time to install the app or connect to a dedicated network. Therefore, research has investigated device-free approaches for making content on a public display relevant. Wang et al. [56] presented the peddler framework for public displays which utilises proxemic interaction to deliver an experience similar to what is found on websites like Amazon, where the interface adjusts as the user comes closer, drawing them in with content that it determines is of most relevance. A similar system is realised by Elhart et al. [21], where they present an approach which enables public displays to detect audience mobility in front of them and automatically schedule content based on the type of activity detected. While a device-free approach can enable public displays to become smarter by implicitly responding to people and predicting what they might be interested in, a current challenge is ensuring the content provided by public displays complements smartphone usage [42].

In summary, the relevance of content displayed on a public display involves two perspectives: (1) whether the content is intended to be relevant; and (2) whether people perceive the content as relevant. Previous work in this area has mostly focused on how to make content relevant on a public display - in our work we observe how non-research public displays present their content and in what ways the content displayed is related to the context of the space and those passing through it.

2.3 Hyperconnectivity

The hyperconnected society stems from the observation that society is generally becoming increasingly connected via the internet [15, 45, 53] enabled through personal connected devices, such as smartphones, smartwatches, and tablets. Personal devices allow us to become hyperconnected and to tap into information available via the internet and connect with each other from anywhere and at any time. As predicted by Manovich [32] in 2006, these technological advances have resulted in an augmentation of public space, creating digital layers that exist over the physical space, causing it to become an intersection of personal and public information [24].

Personal devices have enabled citizens to have new experiences with public space. For instance, QR codes and RFID have seen a revival in recent years, giving objects that exist in public space a form of meta information that can be accessed through a smartphone's camera. For example, a recent successful application of QR codes and RFID in public space has been their use in bicycle sharing schemes, where people can use their smartphones to register bicycles to their account and unlock them for a determined period. QR codes also commonly appear on physical advertisement posters, allowing people to find out more information via their personal device. In regard to public displays, QR codes and RFID are well-established interaction techniques [6, 10, 40, 46].

The rise of personal devices raises questions about the role of public displays in a hyperconnected society. An approach taken in some research studies utilises personal devices for enabling interaction with public displays. Schroeter et al. [50] developed a system for an existing large public display that enabled citizens to voice their opinions on certain topics related to the community, through SMS, Twitter, and Email. Alt et al. [4] studied a public interactive display (PID) network that displayed user generated content posted from a companion smartphone app. These studies demonstrate how a public display can serve as a public broadcast medium, whereby citizens can send messages from their personal devices to public ones, enabling community discourse.

Despite these examples showing promise, more work is needed to understand how non-research public displays have changed in the wild and to understand the effects of personal device usage in relation to user engagement with public displays. This work sets out to gain insights into this and identify ways to enhance public displays through smartphone usage.

2.4 Research Gap

There is a considerable body of work investigating user engagement with public displays. Much work has also focused on how content on public displays can be designed so that it is relevant to users or those that look. However, since Huang et al.'s [29] study, which was conducted 10 years ago, there has not been any research focusing on user engagement with public displays in the wild across a variety of contexts and display types. Motivated by technological advancements and the potential effect of smartphone usage, our work aims to address this gap through a field observation of non-research public displays. Specifically, this research sets out to understand the effect of design elements (RQ1), position and location (RQ2), relevance of content (RQ3), and smartphone usage (RQ4) on user engagement.

3 STUDY DESIGN

Our starting point was to replicate Huang et al.'s [29] study, by adapting their study design to take into account the subsequent changes in technology, observed during our pilot study. The changes relate to public displays being generally larger than previously reported by Huang et al. [29]. We also noticed a lot of smartphone usage from people within public space, which was not reported at the time of Huang et al's study as smartphones were still in their infancy. These changes could have an effect on display blindness, which remains a key challenge for public displays [28, 31, 33, 38, 39]. Therefore, to gain further understanding and to readily support comparisons of display blindness (or attention) across the different displays observed, we decided to depart from the methodology used by Huang et al. [29] to a mixed methods approach, with emphasis on collecting quantitative data.

This section explains how we selected the public displays to include in our study, the data we collected, the methods used to collect the data, and how the data was analysed.

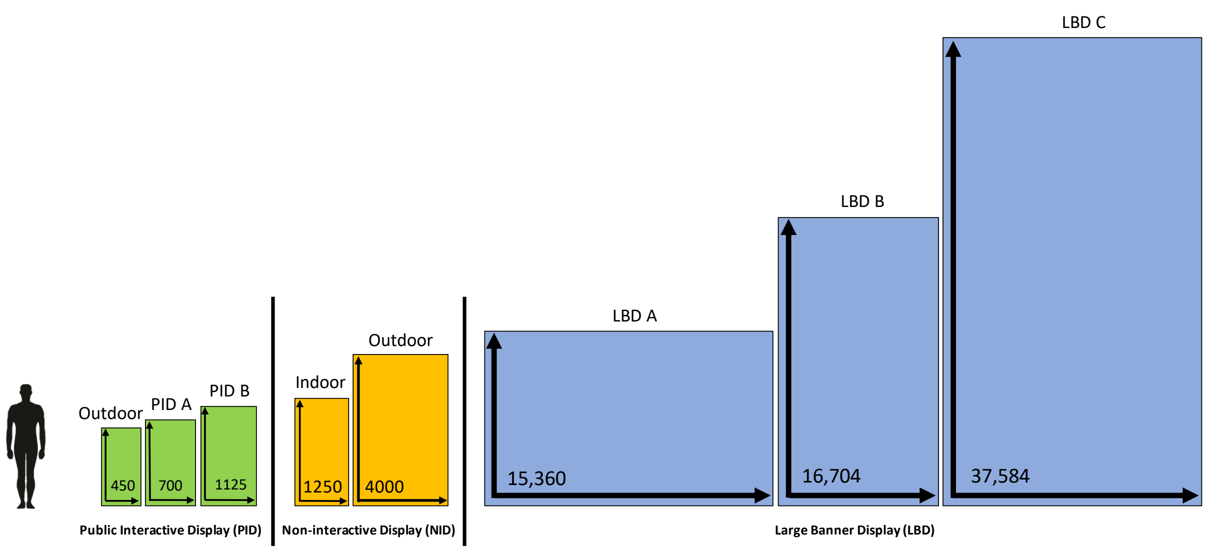

Fig. 1. The three types of public displays observed: Public interactive displays (green), non-interactive displays (orange), and large banner displays (blue). Within each type of public display, the size in square inches (in²) and orientation is illustrated.

3.1 Public Display Selection

We ended up selecting 18 public displays across 8 sites around the city of Sydney. This enabled us to have a broad representation of public displays, ranging from small to large displays, indoor and outdoor locations, non-interactive and interactive, and content related to advertisement and information. While aiming to have a broad representation of public displays and contexts, our selection process was also constrained by access to sites, the necessity to obtain relevant permissions (e.g. to conduct observations in shopping centres), and geographic location as we only studied public displays in one city.

We therefore observed public displays in both indoor and outdoor spaces within the city of Sydney, Australia. Locations were chosen to give contrast to others and gain a broad representation of public display types from different areas. Figure 1 gives an overview of the different public displays observed, detailing the type, orientation, and size. We categorised the findings from our observations based on the type of public display observed. In total, we observed three different types: public interactive displays (PIDs), public non-interactive displays (NIDs), and large banner displays (LBDs).

Table 1. The regions of Sydney the observation was conducted in with the locations and public displays found in each location. The table also includes the distance between each location and the City Wharf, which is a central landmark in Sydney.

Region	Locations	Public Displays	Distance to City Wharf
City	City Wharf	Outdoor PID & NID	0 km
	Chinatown	Outdoor PID & NID	2.2 km
	Business District	Outdoor PID & NID	0.8 km
	Public Square	LBD A	1.9 km
Inner West	Shopping Centre 1	Indoor PID A	3 km
		LBD B	
	Shopping Centre 2	Indoor PID B	2.8 km
	University	Indoor NID	3.7 km
Eastern Suburbs	Shopping Centre 3	LBD C	4.8 km

To give an indication of how spread out around Sydney the public displays were, we outline them in Table 1 with the region of Sydney they were located in, their specific location, and their distance to the City Wharf - which we chose to be an anchor point as it is a central landmark in Sydney.

3.2 Data Collection

The context of a public space can change over time [36], influencing the environment and people that pass through it. Therefore, observations of each public display were carried out over two sessions, once in the morning and once in the afternoon. The morning sessions were conducted between 9:00am and 11:00am, after the peak morning rush. The afternoon sessions were held between 4:00pm and 6:00pm, around the time people typically finish work. Each observation session lasted for 30 minutes, where we observed the behaviour of passers-by around each public display, recording glances, interactions, and any other interesting behaviour. Observations both indoor and outdoor were only carried out on days with good weather, avoiding rain and strong winds as they might have affected how people used each space.

The observation data for our study was collected manually by the researchers rather than using an automated approach through videos [5] or instruments attached to passers-by [17], as we considered this to be the least disruptive to the space while avoiding privacy and ethical issues associated with recording videos within a public space. We also opted to not conduct any interviews with passers-by to keep user behaviour and the space pure, in order to avoid discouraging people from looking at and interacting with the observed public displays [58].

We used a mixed methods approach, where we collected both quantitative and qualitative data. This data consisted of:

(1) A count of passer-by engagement, using a custom developed smartphone app.
(2) Descriptive notes about the space, the set-up of the public display, and behaviours of people in the area.
(3) Photos of the space and the public display. In one case, we were not able to receive approval for taking photos, and therefore sketched the area using a pen and paper.

The count of passers-by enabled us to clearly compare attention and display blindness for each public display. Specifically, we counted the amount of people passing by, looking, interacting, and using a smartphone. The notes, photos, and sketches then added more context to the count of behaviours and helped explain why some public displays were more successful at gaining attention than others.

Throughout the findings section, we will at times mention the exact dimensions of the screen. We only provide this information for public displays where it was possible to gain a measurement, such as public displays within arms reach like touch PIDs. To record the measurement, we used a credit card sized marker and placed it in one of the corners. We then took a photo of the screen and used an image processing application to digitally clone the marker over the entire screen to determine the display's dimension. We used this approach over measuring tape as some screens were too large for us to be able to reach. For displays that were out of reach altogether (e.g. the large banner displays), we sourced the dimensions from the display provider's website or provided an estimate.

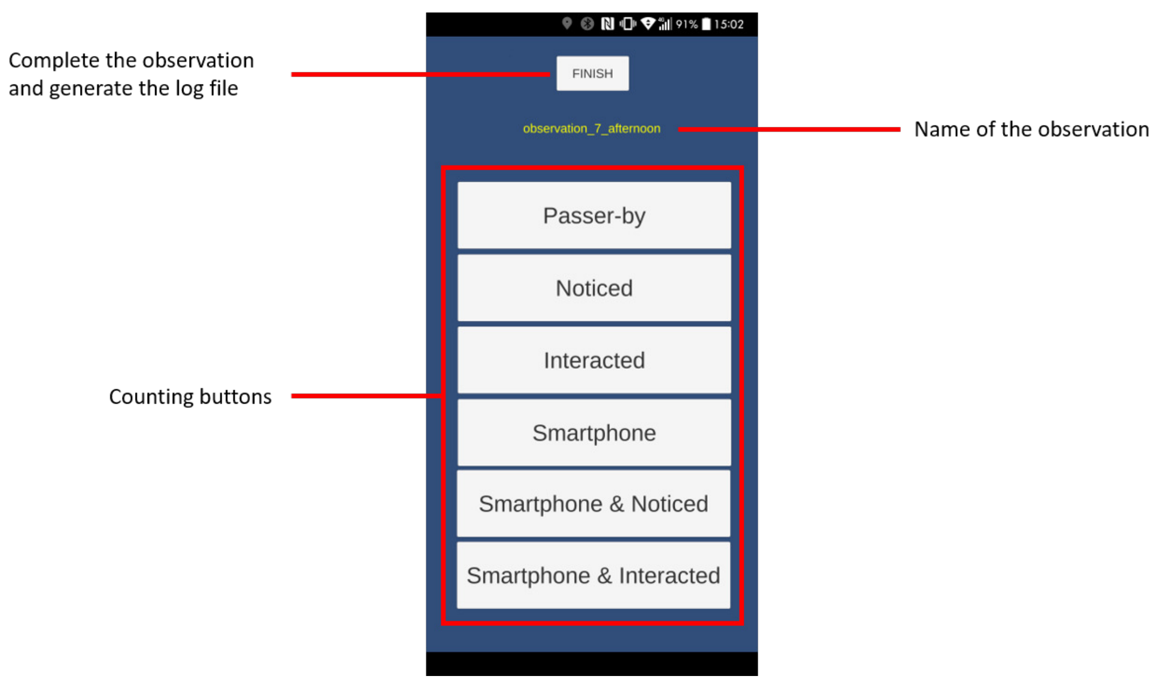

Fig. 2. The counting app used for our observations. It contained six buttons for counting passer-by behaviours with the observed public display.

3.3 Observation Techniques

We applied different techniques for recording data depending on how crowded the space was. In spaces that were not crowded, we utilised the shadow observer technique [29] to focus on individual passers-by and record their behaviour. In busier and more crowded spaces, we used a technique which we introduce as *selective path focus*, where the observer would first observe the permeability of the space and focus only on certain paths passers-by take. This made the observations more manageable, particularly when counting behaviours.

While manually recording the count of passers-by and their behaviours, we noticed in our pilot observations that counting different behaviours required the researcher to look down for a time to record, which reduced their recording accuracy as they would miss passers-by. Recording with pen and paper can also make the researcher stand out in space, affecting people passing through. Therefore, we created a custom-made smartphone app[1] (Figure 2) to ease the counting of passers-by and to allow recording passer-by data without having to look down. The app contained six large buttons for counting particular behaviours of passers-by in relation to the public displayed observed:

(1) passed by without looking or using their phone
(2) looked at the public display
(3) interacted
(4) used a smartphone
(5) used a smartphone and looked
(6) used a smartphone and interacted

The "FINISH" button displayed at the top of the screen completes each session and saves a log file with the name of the observation to the device.

However, even with the app increasing the efficiency of counting passers-by, there were difficulties at times discerning whether passers-by were looking at the public displays. We counted a "look" when someone visibly turned their head towards the public display. Due to the sheer volume of people moving through most of the spaces, we did not record the duration of glances. Interactions were counted when a passer-by explicitly walked up and interacted with the public display, such as touching the screen.

3.4 Analysis

Our analysis started by first aggregating all the collected data, which consisted of photos, sketches, notes, and observation logs generated by our smartphone counting app. We performed our data analysis by specifically looking for common themes emerging from the different sets of data. The photos and sketches were used to help our descriptions of each public display observed, giving us a sense of each space and the spatial arrangement of the observed public displays. With the observation logs, we placed them into a spreadsheet and looked for interesting links between each behaviour observed. We used a colour scale to help identify which behaviour was highest occurring for particular public displays. Our inferences from the observation logs were contextualised with the notes we made during each observation session, further describing the behaviours that were counted and explaining the factors that might be linked to a certain result, such as the environment layout.

4 OBSERVATION FINDINGS

In this section, our findings are categorised by the three different public display types observed during our study: public interactive displays, public non-interactive displays, and large banner displays.

[1]The source for our counting app is available on Github - https://github.com/callumparker/observation-behaviour-counter

4.1 Public Interactive Displays (PIDs)

The PIDs we encountered in our study enabled people to search for information about the space in which the PID is located. In this section, we discuss our observations of three different PID networks that were observed during our study, with one of those networks located outdoors and two located indoors, within two different shopping centres.

Table 2. The count of passers-by and their different behaviours from the morning and afternoon observation sessions with the public interactive displays (PIDs). Total column refers to the absolute total number of passers-by, while the columns to the right of it refer to the passer-by behaviours as a percentage of the total.

>5% >10% >20% >40%

Public display	Total	Passers-by %	Looked %	Interacted %	Smartphone user %	Smartphone & looked %	Smartphone & interacted %
Outdoor PID (City Wharf)	186	87.6	3.8	0	8.6	0	0
Outdoor PID (Chinatown)	73	75.3	12.3	0	12.3	0	0
Outdoor PID (Business District)	408	90.2	2.9	0	6.9	0	0
Indoor PID A (Level 1)	261	88.1	2.7	0	8.8	0.4	0
Indoor PID A (Level 3)	145	86.2	4.8	0	8.3	0.7	0
Indoor PID B (Level 2)	110	83.6	1.8	0	14.5	0	0
Indoor PID B (Level 4)	120	85.8	8.3	0	5.8	0	0

(a) *Morning sessions*

Public display	Total	Passers-by %	Looked %	Interacted %	Smartphone user %	Smartphone & looked %	Smartphone & interacted
Outdoor PID (City Wharf)	539	84.2	3.9	0.6	10.6	0.7	0
Outdoor PID (Chinatown)	376	80.9	11.2	0.5	6.6	0.8	0
Outdoor PID (Business District)	428	83.6	4.4	0	11.7	0.2	0
Indoor PID A (Level 1)	393	87	3.6	2.3	7.1	0	0
Indoor PID A (Level 3)	164	80.5	9.8	1.2	7.9	0.6	0
Indoor PID B (Level 2)	219	90	2.7	0	7.3	0	0
Indoor PID B (Level 4)	67	79.1	6	0	14.9	0	0

(b) *Afternoon sessions*

4.1.1 Outdoor PIDs. The outdoor PIDs are built into a permanent booth structure, containing a payphone and the PID on one side, which is replaced by a static map in some locations, and a large advertisement display on the other (discussed in section 4.2.1). These booths form part of a network managed by an outdoor advertising company. To gain a broader representation of different spatial contexts around the city, we focused on three of these outdoor booths in the following locations: city wharf, Chinatown, and business district. The chosen locations provided a range of contexts, from tourist to business-centric areas.

These PIDs, at first, display an idle screen with the text "*Touch to activate*" and an animated hand performing a touching motion (Figure 3A). Upon touching the screen, users are presented with a menu displaying the current time and date in the top left corner of the screen and four options to choose from displayed as tiles in the centre. The first option, "*Photos*", allows users to swipe through photos of landmarks around the city. In the second option, users could browse a map of the city and search for a point of interest by typing with the on-screen keyboard. The third option displayed the current and future weather of Sydney City. While the fourth option was

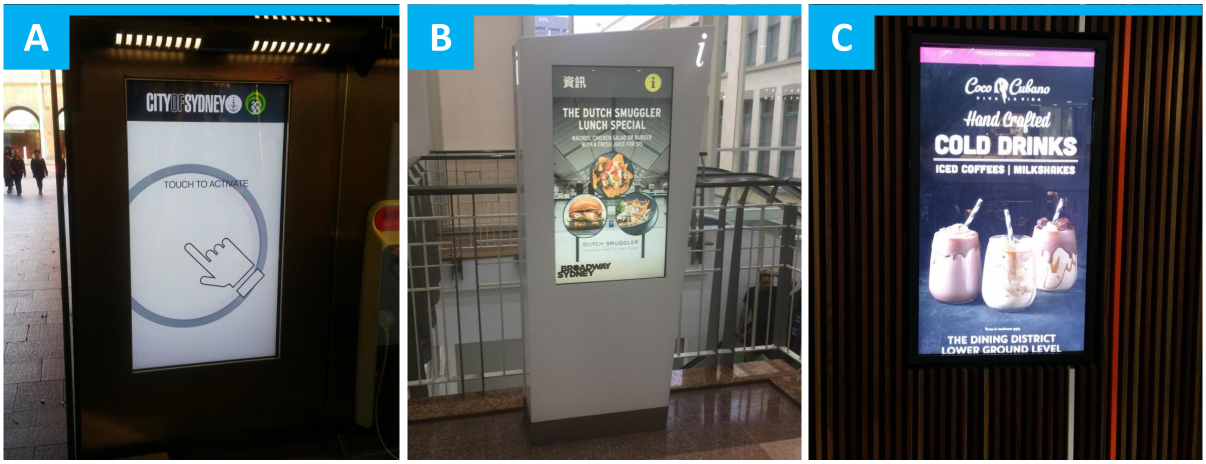

Fig. 3. The different PIDs observed: (A) Outdoor PID; (B) Indoor PID A; (C) Indoor PID B.

similar to the third, as it displayed a map and represented points of interest (such as tourist attractions and train stations) as icons that could be touched to view more information.

The outdoor PIDs were also affected by their positioning and the way they conveyed interactivity. Table 2 shows that despite being the least busiest outdoor space, the Chinatown PID received the most looks, with 12.3% looking at it in the morning and 11.2% looking in the afternoon. This could be explained by the Chinatown PID being situated in a smaller area and therefore the PID was in line of sight for passers-by. The area was also darker due to the tall buildings and trees, which meant the PID's brightness made it stand out more than the others that were positioned in more open spaces.

The city wharf PID, was positioned outside the main path people took when walking through the space, which may have contributed to the low number of people noticing the display, 3.8% and 3.9% in the morning and afternoon respectively. We observed that the PID was facing away from the large crowds of people walking towards nearby tourist attractions. The glare from the sun was also strong in the afternoon, which made the content on this PID's glossy screen hard to see from a distance. The city wharf PID was also competing with static signage, as we observed on two different occasions people referring to a static map that was positioned closer to the main path, making it in line of sight for people passing by. Like the city wharf location, the business district PID also received a low proportion of people looking at it, despite being positioned next to one of the busiest paths in that space. Therefore, it might be that the business district PID simply was not eye-catching enough or that it was not in the line of sight for people passing by. We also noticed that out of the passers-by, a lot walked through the space in groups, often talking with one another, which may have further decreased the amount of people looking.

In terms of interactions, all of the outdoor PIDs had low usage. This may have been due to the positioning of the PID as the advertisement side of the booth always faced the direction where majority of the pedestrian traffic was coming from. Another factor may have been due to the outdoor PIDs not necessarily conveying interactivity or purpose. While the PIDs were idle they would display a splash screen with the text "*Touch to activate*" and an animated hand performing a touch. The top part of the screen displayed a city of Sydney banner with a logo. However, nothing on the screen or booth itself gave indication about the purpose of the PID. Every location also had a significant proportion of smartphone users walking past, with little actually looking up from their smartphones while passing the PIDs.

4.1.2 Indoor PIDs. The indoor PIDs A (Figure 3B) and B (Figure 3C) were situated in shopping centres 1 and 2 respectively. The PIDs allowed users to view information about their respective shopping centres, such as where certain shops were located on a map. While there were many of these PIDs on each floor, we focused on two PIDs from different levels for each of the shopping centres to gain a sense of how a PID's location within a shopping centre could affect usage.

PID A (level 1) was situated nearby the main entrance to the shopping centre, while PID A (level 3) was situated nearby cafés, shops, and the carpark entrance. The PIDs cycled through advertisement content related to the shopping centre when not being used. A whole cycle through the content took 15 seconds, with four pieces of advertisement content. Additionally, the screen would also switch between Chinese and English while idle, translating the top interface ribbon text "*Information*". The Chinese and English translations lasted for 5 and 8 seconds respectively and did not affect the language of the advertisement. The menu interface allowed users to search for businesses and services within the shopping centre using an on-screen keyboard or by selecting a category. Upon selection, the search query's location would be shown on a map of the shopping centre.

PID B was built into the wall next to the elevator on each of the five floors in shopping centre 2. While idle, the PIDs in this location would display full-screen advertisements, cycling through 10 pieces of content at a rate of one every 35 seconds. These directories contained wayfinding information relating to the general stores, clothing shops, restaurants, and restrooms. The language of the interface could be changed by pressing the language button in the top right corner of the screen, which would then bring up 12 different languages to choose from. In this location, we focused on two PIDs from different floors, the second and the fourth. The second floor accommodated cafés and shops, and could be accessed from the street through the main entrance. Unlike the other levels, the wall containing the PID on this level featured a large non-interactive media façade that displayed artistic animations and advertisements, which people were often observed to touch rather than the PID. The fourth floor had a food court with space for dining and did not feature a media façade. Instead, the wall surrounding the PID and elevator was a mirror, which we observed to grab attention of people waiting for the elevator.

The indoor PIDs, PID A and PID B, both had similar functionality but differences in utilisation. As shown in Table 2, PID A was interacted with in the afternoon, 2.3% on level 1 and 1.2% on level 3, while PID B received no interactions. Our field notes suggest that the differences could be linked to the PIDs' positioning and the way they conveyed interactivity. PID A was positioned in close proximity to one of the main entrances. Its position and orientation meant that PID A was in line of sight when people entered the space. Additionally, PID A was contained in a brightly coloured stand with a large glowing "*i*" on top, which may have helped it stand out in the space and indicate that it provides information. We noticed on one occasion the honeypot effect, where a couple interacted with the PID, causing another person to approach and queue for the PID until the couple had finished. On the other hand, PID B was positioned outside of the main path people usually took while in the shopping centre, limiting the audience of these PIDs to those that pass by or wait for the elevator.

4.1.3 Summary. In summary, we found three emerging factors that contributed to certain PIDs receiving interactions. The first relates to placement of the PIDs, our observations show that PIDs positioned in line of sight and nearby the entrance to a space, received more interactions. Therefore, it is important to position PIDs in main paths so they are easier to see and enable opportunistic interactions. The second factor is the way that PIDs convey interactivity, as PIDs should clearly convey their purpose both on-screen and physically, such as signage attached to the PID booth or positioned around the PID. Finally, PIDs should be quick and easy to use. We observed in both the outdoor and indoor locations that people would often refer to static signage rather than use the PIDs. The PIDs we observed generally hid their information behind advertisements or in separate apps, which can potentially serve as a barrier to time-concious passers-by.

4.2 Public Non-Interactive Displays (NIDs)

During our field observations we identified two types of non-interactive public displays that were primarily used for advertising. We observed four of these public displays: one was located indoors in a university food court and the others were located outdoors in a booth.

Table 3. The count of passers-by and their different behaviours from the morning and afternoon observation sessions with the public non-interactive displays (NIDs). Total column refers to the absolute total number of passers-by, while the columns to the right of it refer to the passer-by behaviours as a percentage of the total.

>5% >10% >20% >40%

Public display	Total	Passers-by %	Looked %	Smartphone user %	Smartphone & looked %
Outdoor NID (City Wharf)	189	79.4	13.2	7.4	0
Outdoor NID (Chinatown)	171	79.5	12.3	7.6	0.6
Outdoor NID (Business District)	431	80.7	7.9	11.1	0.2
Indoor NID	80	87.5	7.5	5	0

(a) *Morning sessions*

Public display	Total	Passers-by %	Looked %	Smartphone user %	Smartphone & noticed %
Outdoor NID (City Wharf)	655	86.7	5.5	7.6	0.2
Outdoor NID (Chinatown)	329	69.3	20.1	9.4	1.2
Outdoor NID (Business District)	578	71.1	5.4	23	0.5
Indoor NID	58	96.6	3.4	0	0

(b) *Afternoon sessions*

4.2.1 Outdoor NIDs.

Each outdoor NID (Figure 4A) was contained in a large booth (introduced in section 4.1.1) installed around the city of Sydney. We observed the NIDs in three different locations: city wharf, Chinatown, and business district. The NIDs cycle sequentially through 8 general advertisements that change every 10 seconds. We noticed that the content displayed on the NIDs was exactly the same in all of the outdoor locations we observed and there was no change in the content from the morning to afternoon.

As shown in Table 3, the most popular NID was in the city wharf and Chinatown locations, with the city wharf NID getting a higher amount of people looking in the morning 13.2%, while a higher proportion of people in Chinatown looked in the afternoon, at 20.1%. The proportion of people looking in the city wharf location drastically drops in the afternoon, down to 5.5%. This could be attributed to the large crowds of people walking through city wharf, which may have been distracting. The other possibility could be due to the strong sun glare observed in the afternoon, causing people to look away.

In the case of Chinatown, the high numbers of people noticing are probably due to: (1) the positioning of the display, as it was positioned near the entrance of Chinatown, facing people that came in; (2) The space was closed with not as many paths to take, as there were buildings and trees on either side; and (3) The space was quite shaded due to Chinatown essentially being a large alley, which meant the display's brightness made it stand out. Additionally, Chinatown also had the highest amount of smartphone users noticing it, at 0.6% (morning) and 1.2% (afternoon). Interestingly, the business district had the lowest percentage of people noticing but the highest

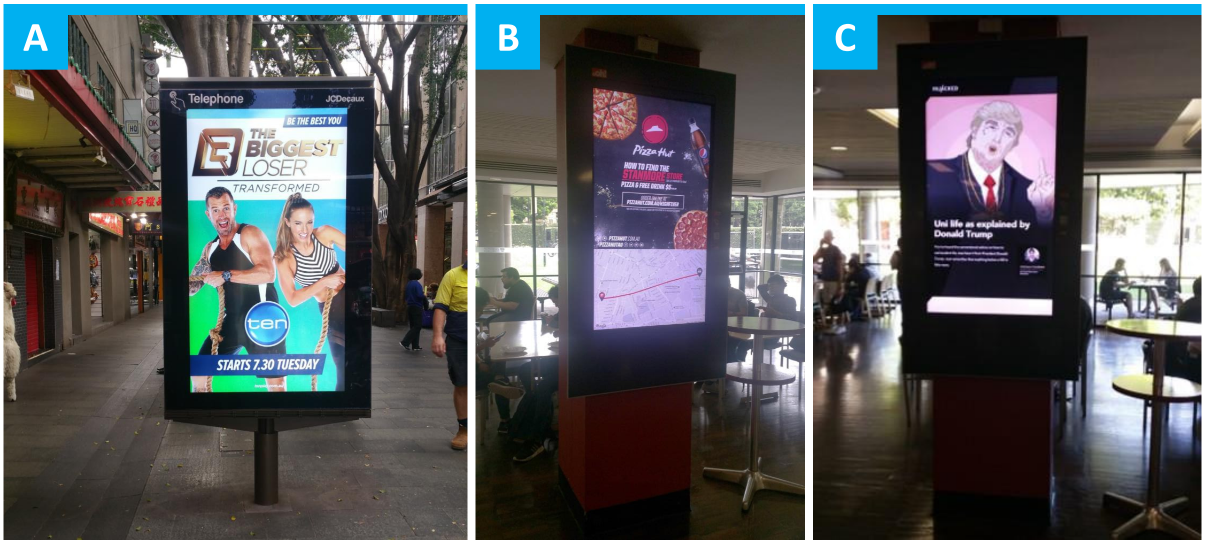

Fig. 4. The different NIDs observed: (A) Outdoor NID displaying general advertisements (same in each location observed); (B) Indoor NID displaying advertising content relevant to the location; and (C) Indoor NID displaying student created news articles (sourced from Universities across Australia).

number of smartphone users, with a low amount of people looking away from their smartphones to look at the display.

4.2.2 Indoor NID. This NID was located within a food court at our university campus. It is a busy space with students gathering together at the tables and purchasing food from one of the food stalls. The NID was specifically situated in the middle of the food court, near one of the main paths to the tables, entrance, and food stalls. The NID we observed contained general advertising content targeted at students (Figure 4B) and news about student life, written as short articles by journalist and student writers (Figure 4C). Students are able to submit their articles on the NID provider's website, where the articles are moderated by the NID provider before appearing on the NID. The content on the NID cycles every 5 to 12 seconds, with articles being displayed longer. We noticed that one of the advertisements for Pizza Hut, displayed a map with the location of the closest store to where the public display was located, indicating that some of the content is tailored for specific locations, as this public display is deployed in universities across Australia. The display also featured NFC and QR code functionality to access the display provider's webpage. However, from our tests with multiple smartphones the feature appeared to not be working.

The location was not busy compared to other spaces we observed. While the NID was positioned in a main thoroughfare, out of the 80 people that walked past the NID in the morning, only 7.5% looked at it. In the afternoon the space was quieter with 58 people walking past and 3.4% of people looking at the NID as they walked past. This may have been due to the content generally consisting of a lot of text, such as the student articles, which would require someone to stop and read. This type of content may not suit the context of this space, with people generally focused on purchasing food.

4.2.3 Summary. The NIDs seemed to be well positioned in their respective spaces, due to the significant proportion of people looking at them. However, the content on these NIDs seemed in general irrelevant to the space. Out of all the NIDs, the only one that displayed location-specific information was the indoor NID, placed inside a university food court.

4.3 Large Banner Displays (LBDs)

We observed the LBDs in three different locations, where one was mounted on an entrance to a shopping centre and the others were hung from the ceiling within two different shopping centres. All of these displays were non-interactive and cycled through a series of advertisements related to either the businesses within their respective shopping centre or general product and service advertisements.

Table 4. The count of passers-by and their different behaviours from the morning and afternoon observation sessions with the large banner displays (LBDs). Total column refers to the absolute total number of passers-by, while the columns to the right of it refer to the passer-by behaviours as a percentage of the total.

>5% >10% >20% >40%

Public display	Total	Passers-by %	Looked %	Smartphone user %	Smartphone & looked %
LBD A (going down)	95	67.5	14.5	17.5	0.4
LBD B (going up)	78	72.1	10.7	16.6	0.7
LBD B (going down)	234	50.6	26.4	20.1	3
LBD C (going up)	290	38.9	43.2	13.7	4.2
LBD C (going down)	269	35.9	42.3	19.2	2.6

(a) *Morning sessions*

Public Display	Total	Passers-by %	Looked %	Smartphone user %	Smartphone & looked %
LBD A (going down)	84	58.8	20.2	19.4	1.5
LBD B (going up)	82	77.3	9.1	13.1	0.5
LBD B (going down)	391	61.1	20.2	17	1.7
LBD C (going up)	427	65.5	20.2	14.3	0
LBD C (going down)	406	61	20.7	17.1	1.2

(b) *Afternoon sessions*

4.3.1 LBD A. This display (Figure 5A) was situated in a public square, which is a semi-outdoor public space with small boutique shops, restaurants, cafés, and public seating. Underneath this space was a large shopping centre which could be accessed by an escalator entrance. In this location, we focused on a banner display that was mounted above the escalator. The content on this display consisted of property investment advertisements in Chinese and advertisements for Chinese and Korean films. Each advertisement stayed on the screen for 13 seconds. People going down the escalator could see the display for 15 seconds before they went under it.

Our observations focused only on people going down the escalator, as the display was facing towards people going down. Due to LBD A's placement, it received a fairly large proportion of people noticing it. In the morning session, we observed that out of the people that went down, 14.5% noticed the display and 17.5% used their smartphones. The afternoon session saw 20.2% noticing and 19.4% using smartphones (as shown in Table 4).

4.3.2 LBD B. This display (Figure 5B) was located in shopping centre 1, which is a five-level shopping centre containing large supermarket chains, shops, and restaurants. Travelators were used to traverse these different

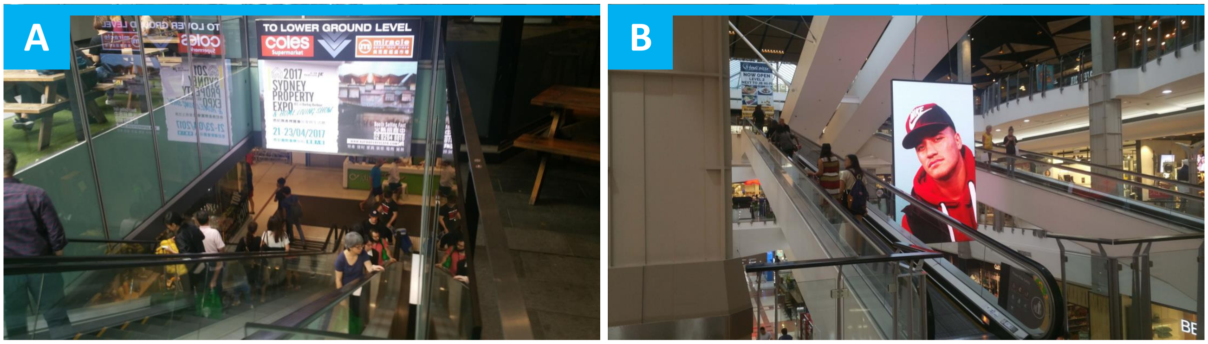

Fig. 5. The different LBDs observed: (A) LBD A mounted above the entrance to an underground shopping centre; (B) LBD B hung from the ceiling between two travelators. No photo for LBD C is included as we did not receive permission to take photos within the shopping centre it was located in.

levels. The display itself was a large dual-sided LED display that was hung from the ceiling and situated between two travelators, which could be seen by people going up and down them. Therefore, we ran four 30-minute observation sessions for this display, to observe people going up as well as down the travelators. These were run as two sessions in the morning (up and down) and another two in the afternoon (up and down).

In the morning session, 10.7% looked while going up and 26.4% looked while going down. However, the afternoon session showed a decrease in the proportion of people noticing, with 9.1% noticing while going up and 20.2% noticing while going down. This could have been due to the travelator becoming more crowded in the afternoon, distracting people's attention away from the screen.

In general, we noticed that most of the glances happened when something changed on the screen, such as an animation or video. There were also times when the screen was clearly noticed by people outside the elevator, as we observed people staring at the screen while walking around level 2 or waiting in line at the juice bar, which is opposite the level 2 travelator entrance/exit.

4.3.3 LBD C. This display was located at shopping centre 3, which features a large variety of boutique shops, cinemas, food courts, and major retailers. In this location, we focused on observing a banner display hung from the ceiling nearby the food court and escalators. The display could be seen from multiple angles and levels, as the space was quite open and the display could be viewed from either side (as it consisted of two LED screens in one enclosure). Next to one side of the display were escalators, enabling a clear view from the side while going up and down the escalators. The display could also be seen clearly from a nearby café seating area. We were not able to include a photo of this display as we did not receive permission from the shopping centre.

Similar to LBD B, we conducted four observation sessions of people going up and down the escalators; twice in the morning and twice in the afternoon. We observed that the banner display cycled through four pieces of content, changing every 10 to 20 seconds. The content on the banner display remained the same during the morning and afternoon sessions, where it displayed a car advertisement, information about a cinema's advance screening, a shopping centre brand advertisement, and an advertisement about free WiFi at the centre. It took approximately 20 seconds to reach the top or bottom when riding the escalator and the display could be seen the whole time as it is so large and in an open space.

During the morning session, there were many people having breakfast in the café seating area, which was close to the display. We observed people looking up and glancing at the display, with one person facing towards the display and watching it while they had coffee. Table 4 shows that in the morning session, this display had the highest proportion of people that noticed out of all the LBDs observed, with 43.2% (going up) and 42.3% (going down). However, the proportion of people noticing decreased in the afternoon session for both directions of the escalator, with 20.2% (going up) and 20.7% (going down).

4.3.4 Summary. Tthe observations from these displays revealed some surprising patterns. Despite smartphone usage being high, large proportions of passers-by actually noticed the displays. Our data shows that (compared to the public displays from the previous two categories) the LBDs were able to attract attention from smartphone users.

While observing the LBDs, we noticed common aspects of people's behaviour across all three locations that may affect whether a public display is noticed. People in groups, such as couples, would often turn around and face each other after stepping on the escalator or travelator, engaging each other in conversation, or collaboratively looking at a smartphone. For some people it was also a time where they could sort items in their bags or look at other people or nearby shop fronts.

5 DISCUSSION

In this section, we first revisit the four research questions we outlined in the introduction section and discuss each of the questions in relation to the findings from our field observations. We then discuss our interpretation of the findings and how these relate to the design suggestions identified by Huang et al. [29], while also providing new recommendations. Finally, we discuss the limitations of our study.

5.1 Research Questions Revisited

(RQ1) What design elements attract attention/convey interactivity?

From our observations, we found that the following three elements helped attract attention: size, structure holding the display, and screen brightness. These are discussed below.

Size matters. Our findings showed that the large banner displays were able to attract the most attention from people passing by, compared to public interactive displays and non-interactive displays. This may have been due to the size of these displays and their positioning near captive audiences, such as those on escalators. In some cases, the large banner displays were able to draw attention even from smartphone users. For ubiquitous computing applications, including smartwatches and other wearable devices, this suggests that interactions with such applications might be affected by other interactive features in the environment.

The design of the structure holding the public display is important. An often overlooked and less covered factor in previous research is the stand or structure holding the public display, which can be utilised to make a public display more eye-catching. For instance, indoor public interactive display A was eye-catching due to the design of its stand, which was painted in a bright colour and featured a glowing information "*i*" on the top; this helped advertise the purpose of the public interactive display and contrasted well with the content on the screen. We further found animated content and the use of videos, particularly on large banner displays, to catch people's attention. On public interactive displays, the idle screen should describe clearly what the purpose of that display is in a way that can be seen from a distance. For other ubiquitous computing applications, this points to an opportunity to consider the design of the surrounding structure and environment in conjunction with designing the application itself.

Screen brightness as an element to attract attention. Screen brightness is important to consider, as it seemed to have an impact on whether people noticed the display. For outdoor public displays, screen brightness can be impacted by the time of day and weather conditions, which should be accounted for in the design of the display; for example by automatically adjusting the brightness of the screen. While this seems like an obvious finding, we did not observe this to be the practice in any of the outdoor public displays we observed. This suggests that screen brightness and visibility also remains an important design consideration in other ubiquitous computing applications. The relevance of context for ubiquitous computing has been studied in previous work (e.g. Abowd et al. [1]), our finding highlights the consideration of contextual factors such as time of the day and weather conditions as well as the concious design of screen brightness as a mechanism for drawing attention.

(RQ2) What is the effect of position and location?

Our findings show a clear correlation between user engagement and the proximity of a public displays to the main path within a public space. We further found that displays in darker spaces tended to stand out more due to the brightness of their screens, and consequently attracted more user engagement. For the outdoor public displays, the effect of sunlight is linked to the position and location of the display, and further dependent on the time of the day. Therefore, it is important to consider the environment in which the public display is situated and how it changes over time as this can affect the visibility of a public display and therefore its effectiveness at attracting user engagement.

We found the large banner displays to be an effective means at engaging people that were as Huang et al. [29] describes, a "*captive audience*" while they were going up and down the escalators and travelators. We observed these displays to also engage people around the space as well, with people sitting nearby noticing them. This creates interesting implications for ubiquitous computing research focusing on large media displays, not only in terms of content and purpose of such media displays but also regarding opportunities for engaging a captive audience in short interactions. To that end, previous research on the use of proxemics in ubiquitous computing applications [9, 23, 56] could be employed to offer different experiences and means of interaction for people depending on their position in relation to the location of the display.

(RQ3) What type of content is relevant?

In the case of the public interactive displays, it appears smartphones have not made them completely irrelevant. We observed occasions where people would queue to gain information about a shopping centre. Outdoors, some people would refer to static signage rather than their smartphones to find a location. Therefore, a need for information about a space still exists, but public interactive displays still need to better advertise their capabilities and purpose. Previous ubiquitous computing research on location-aware systems [3, 12, 49] could be applied to translate some of the functionality of public interactive displays and static signage to smartphones, making it more seamless for people to access relevant information on the go. At the same time, our observations highlight the role of contextually relevant and physically embedded digital information, which is in line with Weiser's original description of ubiquitous computing systems that "*vanish into the background*" [57].

(RQ4) What is the effect of smartphones?

Our findings showed that during most observation sessions, a fairly large proportion of the people passing by used their smartphones. It seems that while the public interactive displays and non-interactive displays were not effective at drawing people's attention away from their smartphones, the large banner displays managed to gain the most attention. This could be attributed to the large size of the large banner displays, their position - near or in the main path of people passing by, and the brightness of their screens. We found that in the case of large banner display C, the combination of the large size, videos, screen brightness, and colour of the content helped it stand out and receive the highest proportion of people looking and people looking up from their smartphones. While we did not observe any occurrences of smartwatch interactions, we expect that smartwatches and other smart, wearable devices will become more popular over the next 10 years. Our findings highlight opportunities for designing the interactions with such devices under consideration of the wider media ecology surrounding the user at different times, such as public interactive displays and large banner displays. From our observations, we found that currently different devices and displays are competing for people's attention. An interesting future avenue could be to design interactions in a way that supports the fluid transition from one platform to another.

5.2 Interpretation - What Has Changed?

Since we concluded that we needed to design our study in ways that are significantly different from Huang et al. [29], there is no simple and strict comparison of detailed results. However, the very fact that we needed to alter the method reflects important changes and we can make meaningful comparisons at a high level. We do this in terms of the Huang et al.'s [29] five design recommendations, where for each recommendation we first summarise the original recommendation and then discuss it based on our own findings and that of previous research. To this set of recommendations, we also add three more that emerged from this work.

Brevity of glances - ***People only pay brief attention to public displays.*** We did not measure how long people were glancing at public displays as it would cause us to miss counting passers-by and can be logistically challenging in busy environments. An emerging method to more accurately determine the length of glances is through eye-tracking [17]. However, this should be approached carefully in order to prevent disturbing the ecology of the space.

Positioning of the displays - ***Public displays positioned at eye-level attract more attention than those that are not.*** Huang et al. [29] recommended that public displays should be positioned close to eye-height to encourage glances. However, the public displays we observed were all generally larger than the public displays observed in Huang et al's study. We noticed that the larger displays, particularly the large banner displays, would receive more attention. This means that the notion of eye-level disappears with large displays as they cover a range of eye-heights. In the case of public interactive displays with touchscreen interaction, careful consideration needs to be paid to the height of the screen as they are ultimately limited by the user's arm length. This could potentially be resolved through adaptive solutions, where the screen adjusts its content based on the height of the user [40]. Such a solution could allow for a display that is large enough to gain attention, while being accessible for everyone.

Content format and dynamics - ***Dynamic content, like videos, attract more attention than static content.*** The content we observed on the public displays ranged from static to dynamic, such as playing videos or sliding through static poster images. The advertising displays showed a broad range of content that was not always related, meaning they were designed for short time viewing rather than keeping someone continually engaged. For instance, people going up or down the escalator near the large banner displays would typically see 1 to 2 pieces of content by the time they reached the other end. While we noticed in our observations that the scale of the displays has become larger, research suggests that public displays can also come in a wide array of formats, from low-resolution lighting displays [27] that are typically used in media façades, to LED displays that are bright and low power. Other work has shown that public displays could be smarter by changing content based on the time of day [20, 42] or conserving power usage by powering off during off-peak times [18].

Catching the eye - ***Permeability and items within the space positioned nearby a public display can help draw attention and bring the public display into the peripheral vision of passers-by.*** While using objects to draw people's attention towards public displays can be effective [28, 29], we found in our study that public displays are more successful at drawing attention when they are: (1) a large size, pervading the peripheral of passers-by; (2) have a bright screen with dynamic content like videos or animations; and (3) the stand or object the public display is mounted to can help it stand out.

Small displays vs. large displays - *Smaller displays are generally better at sustaining longer amounts of attention than larger displays, as the smaller displays are designed for more intimate use, whereas large displays are more exposed.* In our study, only the public interactive displays were of a similar size to the displays studied by Huang et al. [29]. The public interactive displays we observed provided facilities that are relevant and useful for a small proportion of the people in a space - with many of these people likely to be looking out for them or be repeat visitors who already know about the display. Compared with the large banner displays we observed however, public interactive displays did not receive as much attention. We found that the most successful public interactive display was the indoor public interactive display A, as it had physical signage to help it stand out and convey its purpose. Therefore, it is important to balance the size, ensuring the height is suitable for all users while being large enough to be seen.

Aside from brevity of glances, which our study did not test, our observations confirm that the key findings and recommendations from Huang et al.'s [29] study are for the most part already embodied in the public displays we observed. However, based on the findings from our observation study, we suggest three new recommendations to complement Huang et al.'s original recommendations.

Complement smartphone usage. With smartphones and public displays becoming ubiquitous, the availability of both the personal carried device and the embedded public device seems to offer opportunities to create links between the place and the person. This has been investigated in previous research, where a smartphone could enable personalised content on a public display [20, 41]. Other work has explored allowing the user to post content to a public display, thereby enabling situated community discourse [50]. A smartphone can also be used to take content from a display [4, 7], consequently turning the public display into a digital community noticeboard. However, these potential solutions to create a link between private and public technologies do carry the risk of compromising an individual's privacy. Therefore the privacy implications should be explored further.

Communicating purpose. While the design of the content on public interactive displays is important, designers should also focus on ensuring the structure that holds the public interactive display contrasts with the content, helping it stand out and convey the purpose of the display. This could be achieved through signage on the ground or around the display. For instance, the indoor PID A from our study utilised a glowing white "*i*" to indicate it holds information, which seemed to contribute towards it gaining the most attention compared to the other public interactive displays. An alternative is to design a display which could implicitly respond to passers-by, conveying they are interactive [22].

Large banner displays and captive audiences. Our field observation study confirmed that captive audiences are more likely to look at a nearby large banner display. Beyond that, our findings also show that this was true even for smartphone users, albeit at a lower rate. We found that the large banner displays appeared to have been placed to take advantage of captive audiences nearby, such as people on escalators and travelators, waiting in line at a shop, and sitting down. For large banner displays, our results appear to refute the often stated claims regarding display blindness [28, 29, 33, 38], where we found that a large proportion of people would look at the display. Furthermore, we found that the large banner displays were even successful at gaining a significant amount of attention from smartphone users.

5.3 Limitations

We began this work with the goal of performing a replication of the study by Huang et al. [29], with changes to the study methods that take account of the changes since its publication and with the goal of gaining more detailed quantitative results than their methodology supported. The design of our study therefore makes it possible for such studies to be combined to conduct meta-analyses. These could serve to gain insights into temporal trends and richer design insights. The quantitative data could also serve as a baseline for further replications in future work.

We now discuss limitations of our work in terms of each of the key elements of our study design: the selection of displays to study, the data collection, and observation methods. While we tried to observe public displays over a diverse range of indoor and outdoor contexts, such as shopping centres and outdoor thoroughfares; our study was not inclusive of all possible contexts, such as public displays located at bus stops, train stations, and museums. Additionally, as this study was only conducted in one city, it may not be completely generalisable to other cities, such as cities with denser populations or different cultures. Despite this, due to our approach, the results from our study can be readily compared by future work replicating this study in different contexts.

Like the approach taken in Huang et al. [29], we manually collected data to ensure the study was ecologically valid. While the smartphone app greatly helped the speed and accuracy in which we recorded passer-by behaviours, it was still difficult at times to discern whether someone was truly looking at a public display or at something nearby or behind the public display. The manual approach of collecting data also took a lot of time and effort to get right. Pilot studies helped immensely with this as they enabled us to determine the best vantage points to observe from so we had a clear view that was not obstructing other people using the space.

6 CONCLUSION

This article presented findings from a field observation study aimed at offering researchers and designers concrete, ecologically valid knowledge about the use of non-research public displays in the wild by revisiting Huang et al.'s [29] study that was conducted 10 years ago.

Our study shows that over the past 10 years, public displays have become more diversified and ubiquitous, which is likely to increase; as such we found that the different types of displays exposed different design requirements and had different effects on user engagement. For example, we found that for public interactive displays to successfully engage passers-by they need to be positioned nearby an entrance to a space and clearly communicate their purpose. Out of the public displays we observed however, the large banner displays were the most successful at engaging captive audiences, and beyond that, attracted people's attention even while they were using smartphones or being engaged in conversations with others. Therefore, large banner displays clearly have the potential to provide some forms of information at a more usable scale and presentation than a smartphone.

Overall, the analysis of our findings suggests that the effectiveness of public displays at attracting user engagement is linked to a complex set of factors, including elements around the display, its position and location, relevance of the content displayed, and smartphone usage. These factors clearly involve compromises in design and the goals of various stakeholders with roles in defining the content. Our work indicates that it remains a challenge to address these factors. The findings from our study also point to new opportunities for integrating public displays into today's hyperconnected society by considering their purpose in relation to other personal devices, like smartwatches and smartphones. As the adoption of personal devices increases, the competition for attention will also increase.

The key contribution of this work lies in the methodology, where we presented an ecologically valid mixed methods observation approach. We hope the methodology will be taken up by others and that future studies will contribute to a growing and more comprehensive picture of the current and changing state of the attention people give to public displays.

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