Interacting with Computers Advance Access published January 9, 2015

doi:10.1093/iwc/iwu051

Strategies for Intuitive Interaction in Public Urban Spaces

LUKE HESPANHOL* AND MARTIN TOMITSCH

Faculty of Architecture, Design and Planning – Design Lab, The University of Sydney, Sydney, NSW 2006, Australia
**Corresponding author: luke.hespanhol@sydney.edu.au*

Characterised by the increased spread of technology out of workplaces and into public spaces and homes, the so-called third-wave of human-computer interaction has placed greater focus on scenarios that are socially situated, context dependent and not necessarily task oriented. This movement has led to studies investigating how people interact with digital applications in public spaces, but the discussion of intuitive interaction thus far has not been extended to this new realm of user interfaces. Designing for intuitive interaction in public spaces differs from traditional digital applications due to the inherently fluid social nature and often large-scale character of urban interventions. This article discusses the design of interaction for public spaces, based on applications we developed along the years, contrasted to similar endeavours elsewhere. We analyse them through the lens of frameworks for intuitive interactions and derive a series of strategies towards designing for immediate use and high crowd turnaround in urban interventions.

RESEARCH HIGHLIGHTS

- Analysis of different types of interactive public spaces, in terms of spatial layout, distribution of focal points and how people negotiate the space in order to engage in the interaction.
- Classification of urban interfaces into three broad categories according to crowd self-organization around the digitally enhanced environments: performative, allotted and responsive ambient interfaces.
- Discussion of intuitive aspects of interactive public spaces with reference to established literature on intuitive interaction.
- Proposal of user feedback strategies for designing intuitive interaction in public spaces derived from the presented analysis and discussion.

Keywords: HCI design and evaluation methods; Novel interaction paradigms; HCI theory, concepts and models; Interaction design theory, concepts and paradigms; Ambient intelligence; Computers in other domains

Received 17 March 2014; Revised 4 December 2014; Accepted 10 December 2014

1. INTRODUCTION

Interactive public spaces have been the focus of extensive academic research in the past decade (Dalsgaard and Halskov, 2010; Lino *et al.*, 2010). Increasingly, human-computer interaction (HCI) studies have expressed interest in the design and implementation of digital applications that are socially situated, highly context dependent, often not task oriented and addressing scenarios outside of the traditional realms of home and working environments, in an emerging trend that has been referred to as the third-wave of HCI (Bødker, 2006). In particular, the increasing affordability and pervasiveness of digital displays, mobile devices, projectors, sensors, actuators, Wi-Fi connectivity and tracking cameras have facilitated the design of interactive interventions in public urban spaces. A wide range of digital urban interventions has been implemented, from interaction with shopping windows (Dalsgaard and Halskov, 2009), multimedia kiosks (Ojala *et al.*, 2012), digital walls (Ackad *et al.*, 2013; Hespanhol *et al.*, 2011) and situated public displays (Kray *et al.*, 2008) to large-scale artistic installations (Hespanhol *et al.*, 2013; Hespanhol and

Tomitsch, 2012) and media façades (Brynskov *et al.*, 2009; Wiethoff and Gehring, 2012). Despite the variety of end goals (e.g. delivery of new services, promotion of social interaction, implementation of playful public art, etc.), in each scenario the dynamics of public spaces were transformed through the use of digital technologies as tools for augmenting the built environment, with direct impact on the ways the general public would perceive and make use of them.

As in any interactive digital system, designing interfaces that are intuitive and user-centred is also a recurring concern when it comes to digital interventions in public spaces. Urban interaction is still to a large extent an emerging field and, as pointed out by researchers in the area of intuitive interaction, 'for every new technology which has none of its own conventions, a metaphor which relates to something that is familiar to the users would need to be applied' (Blackler and Hurtienne, 2007). Yet, a more focused discussion regarding strategies for intuitive interaction in interactive public spaces is still lacking in the field. By their nature, public spaces pose challenges regarding crowd management and scalability that beg for intuitive approaches in order to ensure the smooth flow of the experience while also taking into account broader norms of behaviour in public and the transient nature of these interactions. In this paper, we present an analysis of interactive design strategies for intuitive interaction, utilizing as examples urban interventions developed by us as well as others [*Section 2. Analysis of interactive scenarios*]. We then analyse them through the lenses of the conceptual framework for intuitive interaction developed by both Blackler *et al.* (2006) and the intuitive use of user interfaces (IUUI) research group from Berlin, Germany (Blackler and Hurtienne, 2007; Hurtienne and Blessing, 2007; Hurtienne and Israel, 2007), pointing out factors that support the intuitiveness of each scenario [*Section 3. Intuitive interaction in public spaces*]. Following that, we discuss mechanisms for feedback observed across the scenarios, presenting approaches for dynamically transitioning between one scenario and another as recommendations to guide the design of intuitive interactions in public spaces [*Section 4. Designing for intuitiveness*].

1.1. Intuitive interaction

The analysis presented in this paper is grounded in the extensive research conducted by Blackler *et al.* (2006) and Blackler and Hurtienne (2007) in the role played by intuition on the behaviour of participants engaging with interactive systems. Through a series of empirical studies, they elaborated a definition of intuitive interaction as a cognitive process that involves utilizing knowledge gained through other products or experiences, is fast and can often be non-conscious. They have also identified that interfaces perceived as intuitive generally allowed users to complete set tasks more quickly, precisely for employing features they would have arguably been previously exposed to in other contexts. The role of *technology familiarity* therefore emerged as a significant factor determining the level of intuitiveness of an interface, supported by the observation that older people usually take longer to complete set tasks than their younger counterparts. From such results, they derived three basic principles of intuitive interaction: (1) use familiar features from the same domain; (2) transfer familiar things from other domains and (3) redundancy and internal consistency. Based on those principles, Blackler *et al.* devised a conceptual framework aimed at assisting with the design of intuitive interactive systems. They developed a *continuum of intuitive interaction*, ranging from elements generally perceived similarly by most people (such as body reflectors (Bush, 1989), physical affordances, population stereotypes and familiar features from the same domain) to more unfamiliar elements that might require mapping through metaphors or familiar concepts borrowed from other domains. All along, internal consistency and redundancy should be considered to support familiarity by a range of different user profiles.

The analysis also makes reference to the research on intuitive interaction conducted by the IUUI group from Berlin, Germany (Blackler and Hurtienne, 2007). Like the studies by Blackler *et al.*, the research carried out by IUUI also reveals the importance of previous knowledge (technology familiarity) to the degree of intuitiveness experienced by users when they come in contact with a new interface. IUUI's approach to the subject includes the proposal of a continuum of knowledge underpinning the notion of intuitiveness, stemming from four different sources in a person's life. According to that approach, knowledge would range from *innate* (reflexes, instinctive behaviour) to *sensorimotor* (basic skills for interaction with the world, acquired in childhood) to *cultural* (acquired through life within a specific social context) and finally to *expertise* (skills acquired professionally and through hobbies). Figure 1 shows the two continua and the relationship between them. Worthy of note for the present analysis, the concepts falling into the sensorimotor category in the IUUI continuum would correspond to

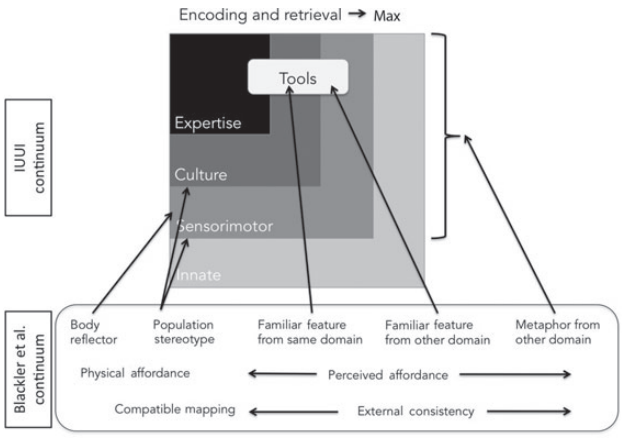

Figure 1. Continua of intuitive interaction and the relationship between them. Based on original diagram by Blackler and Hurtienne (2007).

body reflectors and physical affordances on the continuum proposed by Blackler *et al.* Both approaches are complementary, but while Blackler *et al.*'s focuses on the nature of previously acquired knowledge, IUUI's approach concentrates on the contexts where that knowledge was acquired in the first place. As Blackler and Hurtienne (2007) point out, 'before starting design, the designers need to establish who the users are and what they are already familiar with so that they know what stereotypes, features or metaphors would be suitable to apply'. Designing for urban activation implies designing for a wide range of profiles, age brackets and cultural backgrounds. Given the variety of the audience, technology familiarity—the core element in determining the intuitiveness of an interface—usually also varies quite a lot. As a consequence, the use of physical affordances (body reflectors) is often favoured, for addressing basic behavioural patterns common to all humans. In terms of the IUUI research group framework for intuitive interaction, such use can be characterized as addressing innate and sensorimotor knowledge, derived from the common denominator factor of having a human body. That fact, in turn, ensures its universal applicability and makes employing physical affordances a powerful strategy when designing for intuitiveness.

Antle *et al.* (2009) have demonstrated, however, that mental models derived from physical affordances are not by themselves sufficient to imply intuitiveness. Drawing from the work of Lakoff and Johnson (1980) on metaphors and embodied schemata, they investigate intuitiveness in responsive environments based specifically on full body interaction. *Embodied schemata* are mental representations of recurring dynamic patterns of bodily interactions that structure the way we understand the world; *embodied metaphors* conceptually extend embodied schemata through the linking of a source domain that is an embodied schema and a target domain that is an abstract concept (e.g. the body's general upright position in space implies various spatial metaphors based on a vertical hierarchy). Structuring their study around a responsive auditory environment, Antle *et al.* ran a comparative study of the same setup using two different mapping strategies: one where gestures were based on embodied metaphors and another where they were not. Results demonstrate that a mapping constructed on embodied metaphors leads indeed to greater non-conscious interaction; however, this appears not to be sufficient: in order to be intuitively enacted, the mapping should also be easily discoverable. The research therefore points to the significance of perceivable feedback in the construction of input actions interpreted as intuitive. Later in this paper, we link their results to our own discussion on the utilization of different feedback strategies in the design of specific types of responsive environments.

1.2. Interactive public spaces

In general terms, public urban spaces can be characterized by sharing the basic features of *open accessibility* and *open multi-sensory policing* (Cook and Laing, 2011). Open accessibility refers to the high porosity of open public spaces, welcoming a wide range of citizen profiles (e.g. age, gender, social level or ethnic background), with little or no external crowd control mechanisms in place. Open multi-sensory policing, on the other hand, refers to the fact that such spaces allow for mutual observation of acts carried out within the area by agents not directly involved in the interaction, like observers in the periphery of the space, CCTV cameras and local shops. Such mutual observation process, though manifested chiefly through visual contact, usually occurs through a combination of sensorial input (for example, sounds produced by a person in the space are likely to be readily observed by other people nearby). Rather than being enforced rules for social interaction, in those spaces people are therefore left to self-organize according to tacit norms of public behaviour (Goffman, 1963)—including self-regulation through mutual surveillance (Kray *et al.*, 2008). Such traits pose particular challenges to the design of interactive systems embedded into urban localities.

Interactive public spaces are thus characterized by two core features, derived respectively from their inherent open accessibility and open multi-sensory policing: (i) the digital interactive system is (to a greater or lesser degree) blended into the built environment surrounding the participants and (ii) multiple people can simultaneously partake in the interaction. In simpler terms, (i) participants are inside the system and (ii) there are other people in there too.

Due to the participatory nature of public spaces, intuitive interaction in such environments serves a purpose that goes beyond what is observed for more traditional device-based private computer interfaces: in addition to facilitating HCI by relating to familiar features experienced elsewhere, it also aims to ensure that the particular modes of social organization adopted by the crowd in the urban precinct does not deviate from the design objectives. For example, a digital display designed for interaction by individuals or small groups of people should clearly communicate its restrictive character to its potential audience and discourage a larger crowd from attempting to also join in the interactive experience. Conversely, ambient digital installations should clearly convey their non-interactivity to passers-by and nearby observers, in the interest of effectively communicating their content.

As a consequence, core concerns underpinning the design of interactive experiences in urban spaces include: (i) to give clear feedback about who is in control of the interface at any given time; (ii) to clearly indicate what each participant is in control of and (iii) to analyse the roles assumed by (and hence the content conveyed to) people participating in the interaction as opposed to those observing from outside the interactive zones. In other words, intuitive interactive mechanisms ought to be devised to match the physical layout of the augmented space so that potential participants, almost without thinking, are able to negotiate their roles within the interacting crowd and seamlessly transit between their perceived personal space (micro-space) and the broader interactive environment

(macro-space). Likewise, the content communicated by the digital interface must cater for both the participants directly engaged with it (operating in their micro-space) and those individuals standing at the periphery of the space (and therefore capable of appreciating the broader macro-space). In light of the frameworks for design of intuitive interaction, the spatial layout and feedback mechanisms whereby the interface present itself to passers-by in the urban environment should draw upon their regular social interaction as well as similar technologies they may have been previously exposed to in order to achieve a level of sufficient familiarity to be perceived as intuitive.

1.3. Current models

Designs of large interactive public environments have traditionally resorted to two main weapons of choice: *mobile devices* and *gesture-based full body interactions*. The first leverages from the increasing ubiquity of handheld, portable and computationally powerful devices (particularly smartphones and, more recently, tablets) as a mediator between users of a public space and specific digitally augmented spots (usually electronic displays or media façades) within the precinct. They offer the advantage of minimizing a participant's public exposure and consequently are relatively effective in encouraging opportunistic interaction (Kray *et al.*, 2008) by reducing the perceived risk of social embarrassment. On the flip side, their utilization for such purpose is novel and unrelated to their usual mode of use, compromising its intuitiveness. It poses challenges to the scalability of the interface, raising issues regarding concurrent access between parties that are largely unaware of each other. Moreover, it also poses a practical barrier to the spontaneous emergence of interaction in the urban space, since it requires people to install an app or navigate to a website, which in turn needs to be communicated.

Gesture-based interfaces controlled via full-body interactive mechanisms have generally come to be associated with the term natural user interfaces (NUIs). They refer to settings that allow interaction with digital systems to take place without the presence of any specific device operated or worn by the user, leveraging from people's innate skills of using their bodies to interact with the world. Yet, it can be argued that many of the in-air gestures proposed as innate—such as 'grabbing to pick up' or 'pushing hand to select' (Microsoft Corporation, 2013)—are distant from the actions people would intuitively take when dealing with most products or digital interfaces. In other words, although such tracking technologies present a necessary step towards more natural interactive mechanisms (in the sense of being based solely on the human body), in their current stage they can hardly be regarded as natural—or intuitive—themselves. As a consequence, concerns about intuitiveness and effectiveness of mid-air gestures have become the subject of much of recent research in the field of NUIs (Hespanhol *et al.*, 2012). In reality, many of the proposed gestures require learning when employed for the first time; when proved effective, however, they often proceed to become accepted best practices for interaction design in this new domain (Microsoft Corporation, 2013). They also tend to be perceived as familiar by users in the field and therefore intuitive to those who had acquired such expertise (Blackler and Hurtienne, 2007).

The level of intuitiveness of either strategy when applied to interactive public spaces is largely dependent on the type of interactive scenario designed, which is in turn strongly influenced by the physical layout of the space and the narrative adopted for the interaction, as we will discuss in the next section.

2. ANALYSIS OF INTERACTIVE SCENARIOS

Interactive public spaces are naturally social environments: having a larger than human scale, they aim to address multiple users of a particular public space simultaneously. When designing intuitive interfaces for public interaction, such a multiplicity of participant profiles becomes therefore a core concern: interactive strategies incorporated into the design must draw from concepts perceived as familiar across the board. As a consequence, expertise knowledge is less favoured than knowledge that is innate or sensorimotor (body reflectors). Cultural perceptions shared by the members of the public can also allow references to population stereotypes, familiar features from the same or other domains, as well as the use of metaphors. Figures 2 and 3 illustrate how the design of interfaces for public interaction relates to the frameworks for intuitive interaction defined by the IUUI research group and Blacker *et al.*, respectively. A balance between the physical layout of the interactive environment and the interactive narratives adopted determines how the behavioural patterns of a group of people gets affected, leading to distinguishable forms of individual and crowd self-organization driven by technology.

For the present discussion, we considered previous examples of urban interventions in public spaces developed by us as

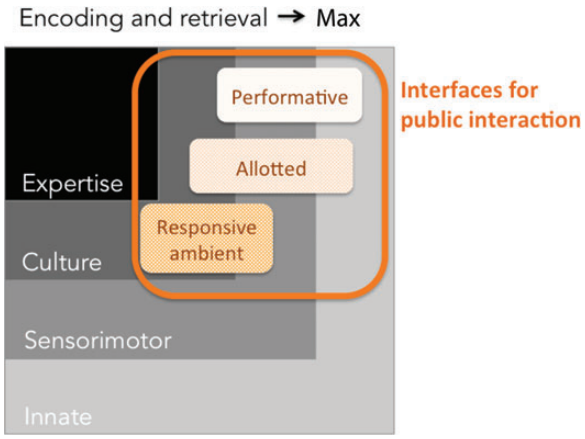

Figure 2. Public interactive spaces in the context of the IUUI continuum of intuitive interaction. Based on original diagram by Blackler and Hurtienne (2007).

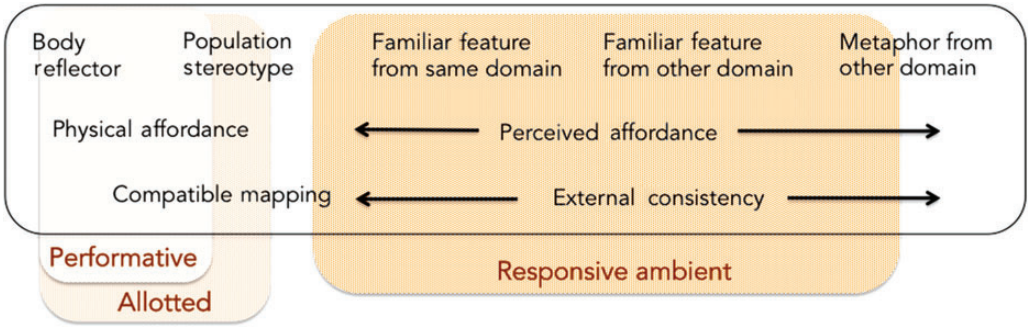

Figure 3. Public interactive spaces in the context of the Blackler *et al.* continuum of intuitive interaction. Based on original diagram by Blackler and Hurtienne (2007).

well as others. We analysed these examples in terms of how the crowd negotiates the space around the interfaces to engage in the interaction and identified three broad categories for social organization around digitally enhanced environments: performative, allotted and responsive ambient interfaces. In the following paragraphs, we discuss each of those categories in more detail in light of the case studies we utilized to identify them. As we will discuss later, the nature of each of those scenarios—as well as the design goals driving them—determine different strategies in designing intuitive interactive mechanisms for their audiences.

2.1. Performative interfaces

Performative interfaces are characterized by promoting highly visible and direct interaction by a limited number of participants. They usually take the form of screen-based interactions (media façade, digital billboards, interactive walls, etc.) driven by clearly delimited interactive zones. This clear delimitation, coupled with the constraints about the low number of simultaneous participants, leads to a natural division in the audience between those engaging in the interaction—the *performers*—and those passively watching from the outside—the *observers*. The classical *honeypot* pattern described by Brignull and Rogers (2003) is therefore a distinctive feature of such scenarios, intuitively derived from the cultural familiarity with other performative experiences (such as plays, concerts, street performance, public speaking, etc.).

Some performative interfaces can cater for small groups of simultaneous performers, who then collaborate transforming the content of the interaction during their shared engagement. Likewise, the existence of the installation may occasionally also serve as conversation starter between observers (Hespanhol *et al.*, 2014a, b; Tomitsch *et al.*, 2014). Social interaction (Ludvigsen, 2005) among members of the audience within such scenarios occurs therefore via social triangulation (Memarovic *et al.*, 2012), i.e. impromptu conversation between people mediated by the urban interface.

Figure 4. Performative interface, creating a clear and spontaneous separation of audience members between performers and observers. Top: performers around *Liquid Light*. Bottom: screen detail of two people interacting with the interface.

Many digital interactive installations in public spaces have adopted a performative approach. *Liquid Light* (Hespanhol *et al.*, 2011; Hespanhol and Tomitsch, 2012, 2014) (Fig. 4) is a work we developed in 2011 at the University of Sydney, as part of an interactive media night event (it has also been exhibited in other venues later). It consisted of a medium-sized LED screen positioned so that it faced an outdoor area in the courtyard of a faculty building. An infrared camera was positioned on top of the display to track the audience. As people walked in front of the screen, they could immediately see their silhouettes reflected on the screen in the form of luminous outlines against a pool of dark water, which sent ripples through the image as they moved around, accompanied by a distinctive melody. Additionally, whenever two or more people were tracked, luminous halos would connect the top of their heads, expressing their newly established social bond. Other studies well documented in the

literature that could be qualified as performative interactions are *Aarhus By Light* (Brynskov *et al.*, 2009), an interactive media façade at the Concert Hall Aarhus in Denmark, where people stepped into stage zones delimited by colourful carpets and interacted with their silhouettes displayed in a very large LED screen installed at the building façade; and *SMSLingshot* (Fischer and Hornecker, 2012), an installation allowing people to throw 'light painting' messages via projections on a wall using a mobile device in the shape of a wooden slingshot.

2.2. Allotted interfaces

When the interface is large enough to accommodate multiple participants interacting simultaneously with the system, the abovementioned performative setting evolves into a particularly distinctive form of crowd dynamics. Although a division of the crowd between performers and observers can still be claimed, it becomes less pronounced as participants spread out along the full extension of the interface. Likewise, it becomes harder for each individual interacting to pay attention to the actions of the other participants other than those in their immediate vicinity. That leads to an individualization of the interface usage, which in turn extends way beyond the reach of each single individual. We propose the term *allotted* to define such interfaces, borrowing from the models of communal gardens (allotments) adopted by small communities in many countries as an approach for democratic, bottom-up organization and self-management (Acton, 2011). In such arrangements, each individual is granted their own plot of land to work on and, despite having to abide by the general terms and conditions of the scheme, the activities there conducted are usually of private nature. Participants on such scenarios are naturally aware of the fact they are part of a broader group; however, the focus of their interaction is usually centred on themselves and on their peers in the immediate vicinity. Social interaction may occasionally occur between neighbours in the space, though that is usually less relevant when compared with their individual experience. Due to the large scale of the interface, participants often get the impression of being in direct interaction with the surrounding environment (as opposed to a localised interface, such as a small or medium-sized electronic display).

In allotted interactive public spaces, the individual 'plots of land' are actually often of variable dimensions and location, given that people are frequently moving around the space. A dynamic negotiation of space and ownership of the interface therefore unfolds, with each participant continuously reassessing their positioning within the environment in reaction to both the feedback gained from the interface itself and to the movements of other neighbouring participants. From an outside observer, a *swarm* pattern thus emerges—similar to a flock of birds or a school of fish—where the sum of discrete and cumulative negotiations between individuals determines the broader changing dynamics observed at the crowd level.

Figure 5. Spontaneous allotment of *Solstice LAMP*'s interface. The performance is distributed across the space by allowing each participant to interact on their own share of the interface.

Participants form a *community of circumstance*: a group of people united by sharing common spaces and activities, but not necessarily unified by a common goal (as it is the case with performative spaces).

Such a pattern was clearly observed in one of our recent installations, *Solstice LAMP* (Hespanhol *et al.*, 2013, 2014b), a large-scale urban intervention developed for a prominent light art festival in Sydney, Australia. It consisted of two sections: (i) an interactive ground zone, where overhead infrared cameras would track passers-by and trigger the real-time projection of silhouettes and other visual effects on the floor around their bodies and (ii) a building façade, where pre-programmed laser patterns would be projected on as a consequence of the crowd movement at ground level. As illustrated in Fig. 5, people naturally took up their positions within the space and conducted their interaction locally with disregard for the overall state of the environment. Proactive interpersonal interaction happened among acquaintances, but it was limited by social norms when applied to strangers nearby, with distance between participants being negotiated according to cultural conventions regarding personal space (Hall, 1966). Notably, such conventions were often ignored by children, arguably more exposed to family environments and with less acquired

cultural knowledge (Blackler and Hurtienne, 2007) of such social conventions for behaviour in public.

Body Movies (Lozano-Hemmer, 2001), by Mexican-Canadian artist Rafael Lozano-Hemmer, is another example largely documented in the literature that can be qualified as an allotted interface. Here, participants interacted with their shadows cast on a building façade. As in Solstice LAMP, each participant was free to take up a portion of the interface to conduct their own experience, which was in itself independent of their peers'. Self-organization of the space and swarm-like social interactions (Ludvigsen, 2005) also occasionally emerged, with people engaging in visual conversation via social triangulation (Memarovic *et al.*, 2012) through their shadows on the façade. It is worth to note that allotted interfaces are not restricted to full body interaction mechanisms: simultaneous engagement by multiple participants through mobile devices—such as iRiS, the interactive media façade developed by Wiethoff and Gehring for the Ars Electronica pavilion in Linz, Austria (Wiethoff and Gehring, 2012)—elicits a similar swarm pattern for usage and spatial self-organization. Here, however, each individual is represented by a pointer or avatar in the interface (in the particular case of iRiS, light-based spray paint), rather than their own physical bodies.

2.3. Responsive ambient interfaces

At the opposite end of the spectrum from performative interfaces are those that, despite responding to inputs from the audience, are purposely designed not to appear interactive. Reasons for that may vary; for instance, the work may be installed in a zone where the congregation of a large crowd is undesirable. Under those circumstances, rather than giving passers-by direct feedback and inviting them to engage in performative interaction with the interface, the design tries to spread their focus to elements on the environment around them. In addition to being more diffused, feedback is also often delayed, with the passer-by only realizing its occurrence after the event, in an expression of the *landing effect* (Mueller *et al.*, 2012). While people observing from outside the environment are able to perceive its responsiveness, interaction with the digital interface is indirect and participants themselves are often unaware of their 'performance'.

An example of responsive ambient interface is *Chromapollination* (Hespanhol and Tomitsch, 2012), a temporary site-specific work we designed for an area adjacent to the entrance to one of the busiest rail stations in Sydney, Australia. Part of the brief was, therefore, to create a digital environment that could respond to the public without causing pedestrian traffic congestion in the area. The work consisted of three sculptural elements of dandelion flowers arranged in a triangular configuration and embedded with fibre optics and movement sensors pointing at both the centre of the space and its surroundings. Above the elements, a triangular LED screen hovered over passers-by (Fig. 6). As they walked around and across the space, their movement would be tracked and generate a 'digital wind', triggering 'pollination' events between the flowers, represented by a stream of light from one flower to another played on the overhead LED screen. The colour of the stream would cause the colour of the target flower to change, so that the environment was continuously responding to the crowd, although not in a direct manner. In most cases, participants could not determine the lighting patterns had changed in response to their actions and the overall impression about the work was of an ambient digital environment regularly changing at random.

Chromapollination was, by design, intended to avoid direct feedback, prompting passers-by to focus instead on their surroundings rather than on their performance. Likewise, observers standing outside of the interactive zone would not interpret those inside the space as performers, rather directing their focus to the overall dynamic state of the environment. The interactive mechanisms were intuitive given human's familiarity with real flowers: people are used to observing the effects of the wind on vegetation, though, on such large scale, they normally have no direct control over it. This encourages the perception of an inherently passive and non-interactive (although responsive) environment. The feedback given by the installation was, therefore, not easily perceived as being caused by any specific individual, and that was our intention as designers.

Although not conceived with the intention of being a responsive ambient interface, the urban intervention *The*

Figure 6. *Chromapollination*, a responsive ambient public space. Patterns of light change in reaction to movements of the crowd across the space, but the response is purposely delayed and does not address any individual in particular.

Table 1. Types of interactive public spaces.

Design aspect	Performative interfaces	Allotted interfaces	Responsive ambient interfaces
Predominant pattern	Honeypot	Swarm	Landing zone
Awareness of interaction	Audience fully aware of performance	Participants aware of individual and social interaction	Participants unaware of interaction
Main focus of interaction	Stage	Personal space and peers immediately nearby	Environment

Climate Wall (Dalsgaard and Halskov, 2010) represents an interesting example of how counter-intuitive design can cause a digital urban intervention to invite an unintended type of performance, or be perceived as ambient altogether. Conceived with the purpose of prompting participants to take part on the debate about climate change, the work consisted of words associated to the theme projected on a street wall from temporary towers across the street. As people walked past the wall, they were tracked and the words above their heads were dragged around, allowing them to form sentences contributing to the debate. What the authors observed, however, is that rather than actually making any meaningful statement, most people were instead limited to engage with the playful elements of the interface. Many others interacted by accident, merely walking along the wall and dragging words around, failing to realize the environment had just responded to their movement—or realizing it and then rushing to walk out of the interactive zone. As the authors pointed out in a later analysis, there was a clear mismatch between design goals and actual participant behaviour, since the interaction zone was the pavement along the building, whereas the projection on the façade was best viewed from the pavement on the opposite side of the street (Dalsgaard and Halskov, 2010). Besides, the vocabulary used was relatively complex and did not allow for proper grammar. In other words, its intended use was unfamiliar and hence counter-intuitive. The work could be best appreciated by observers outside of the environment (across the street) than by people engaging with it, many of whom did so unwittingly.

Table 1 summarizes the core characteristics of the three types of interactive public spaces considered in this analysis.

3. INTUITIVE INTERACTION IN PUBLIC SPACES

Although the three types of interfaces presented propose very distinctive interactive scenarios, the fact that they are all set in public urban spaces establishes two very important shared—but conflicting—concerns for their design. The first concern is the inherently transient nature of public urban spaces. Since people are allowed to walk in and out of the zones at their own leisure, encounters are mostly fluid and last only for the short term. Starting such interactions should thus be a seamless process, immediately learned and performed almost unconsciously—in other words, interfaces for interactive public space would generally benefit from intuitive interactive mechanisms. As pointed out by Mueller *et al.* (2010) in their discussion about the nature of public displays, 'With making displays interactive users need to be motivated to make use of these systems and need to find an incentive for using them. Typically people do not go out in order to look for a public display to use.' The second concern is the need of catering for a wide variety of potential participant profiles, diverse in age, gender, cultural background and, therefore, technology familiarity—one of the core factors determining the intuitiveness of an interactive digital experience. Malone (1981) and Mueller *et al.* (2010) argue that 'on the basis of his or her prior experiences the user should have initial expectations for how the interaction proceeds, but these should only be partially met' so that a certain incentive exists to carry on with the interaction past the very initial encounter. We argue, therefore, that intuitiveness in such scenarios may be strongly derived from the very basic level of the interactive experience: *feedback*. As pointed out by Norman (2004), what an individual can do with a digital interface is determined not only by the physical affordances of the device or digital environment itself, but largely by affordances *perceived* from the feedback received. It is the responses given by an interface to the actions performed on it that set in motion the process of interpreting and making sense of its behaviour. Such affordances are not an obvious consequence of having a human body, but features learned out of similar interactive experiences. Blackler *et al.* (2006) observed that perceiving such affordances is a direct product of technology familiarity—i.e. the previous exposure of an individual to similar digital features. Feedback that builds upon cultural and technological conventions is, therefore, instrumental for an interface to be perceived as intuitive. For the same reason, the feedback must be clear and consistent. As the research from the IUUI group puts it, 'after any operation users must get immediate, self-evident and appropriate feedback from the control itself or via display. Users should have no uncertainties about the result of their action because this may interrupt the intuitive flow of operation' (Blackler and Hurtienne, 2007). Antle *et al.* (2009) also emphasize how strongly clear feedback mechanisms contribute to the intuitiveness of an interface. Although experiential cognition (Norman, 1993) has been largely observed on their studies as being coupled with embodied metaphor-based interaction, even in scenarios where this was not the case reflective cognition would facilitate a swift

interaction as long as the feedback given by the interface was easily discoverable, clear and unambiguous. Moreover, in both scenarios participants demonstrated a predisposition to explore and interpret the environment spatially. When it comes to the design of responsive spaces where technology is embedded into the built environment, familiarity and discoverability ought therefore to be expressed not only in terms of the nature of the digital feedback given to people experiencing the interaction, but also in regards to its physical distribution across the space (i.e. the direction the feedback may be coming from). For that purpose, we argue that feedback strategies can be further divided into (i) feedback to the passers-by when they first encounter the interactive environment; (ii) basic direct individual feedback given on their actions and (iii) general feedback given to everyone in the space.

In the next subsections, we first describe the concerns underpinning the design of interactive public spaces; then, we discuss the feedback mechanisms given by each of the presented types of environments in light of the principles for intuitive interaction developed by Blackler *et al.* (2006). There are several examples of interactive public spaces where the observed behaviour of the general public does not match the interactive goals the interface was designed for (Ackad *et al.*, 2013; Dalsgaard and Halskov, 2010; Jacucci *et al.*, 2010; Valkanova *et al.*, 2014). By focusing on methods for encouraging intuitive interaction in core types of public interfaces, our analysis expects to address such issues previously identified in the literature.

3.1. Arguments supporting intuitive interaction in public spaces

The transient nature of public spaces demands that interactive urban environments are designed around interfaces that allow immediate learning and use. Jacucci *et al.* (2010) pointed out that a 'walk-up-and-use' system needs to be so self-explanatory that first-time or one-time users need no prior introduction or training. It should involve aspects of presence, flow and intrinsic motivation, and unpack content gradually in order to enable sustained interaction. Models for interaction with digitally augmented public spaces are arguably still not very well established; however, a trait common to all the scenarios here presented is the pursuit of interactive mechanisms that can be perceived as intuitive from the outset. Passers-by coming into interaction with such environments should be presented with an interface that is sufficiently transparent to allow immediate engagement with its content. Also, the interface should promote a feeling of empowerment by allowing people to feel as if it responds to their actions 'naturally'. In that sense, they should perceive themselves within the public space less as a user of a digital application and more as a participant co-creating the public interactive experience.

The main point of distinction between the three interface types presented relates to the level of accessibility to the interactive interface by the general public. Interfaces that allow none (responsive ambient) or only a few (performative) participants have, by design, greater control over how people get to engage with them and, consequently, less need of enabling intuitive interaction as an entry mechanism. For example, during the operation of a performative interface a distinctive stage-like area emerges right in front of the screen: a few people interacting with the content a few steps away from the display, while the rest of the audience observes their actions from the periphery of the space (Brignull and Rogers, 2003). The dimensions of the interactive space—more precisely, the number of *access points*, or physical spots people can freely engage in direct interaction with the interface—determine the number of simultaneous participants. In other words, the spatial layout of the environment poses a physical affordance encouraging or discouraging simultaneous interaction by multiple participants, dictating particular applications of sensorimotor knowledge acquired through life and processed largely intuitively (Blackler and Hurtienne, 2007). Importantly, in performative scenarios all participants are engaged with the same content fully visible on the screen. Actions from one participant necessarily affect all the others and, consequently, all participants are aware of each other all the time. In an allotted interface, a large number of points are available for simultaneous and largely decentralized access. Subject to little control by the system itself, interactions in allotted interfaces are self-regulated according to the dynamics of the swarm (i.e. social interaction between individuals and their immediate neighbours in the space). Responsive ambient interfaces, in turn, benefit from discouraging direct interaction by offering little or no access points to the interface. The design of ambient scenarios should therefore lead participants to intuitively discard direct engagement with the interface. In terms of the intuitive interaction continua, we can argue that the design of performative and allotted interfaces deals, in its core, predominantly with body reflectors and—particularly in the case of allotted interfaces—population stereotypes that help to guide a crowd to negotiate the space and self-organize. Conversely, responsive ambient interfaces favour a sense making process driven to a great extent by shared cultural knowledge, refraining from utilizing body reflectors that could otherwise convey any form of direct control by participants; rather, they rely on population stereotypes, familiar responsive features from the same or other domains and metaphors that assist communicating its ambient character (Fig. 3).

The social pressure derived from interactions taking place in the public arena is arguably another factor discouraging many people from engaging with the interactive environment. Potential participants are fully aware of the public nature of the situation. Anxiety for not complying with the tacit social roles normally assumed in the presence of strangers (Goffman, 1973) can lead to fears of social embarrassment and damage to their social acceptability (Rico *et al.*, 2010). Again, that points to the recurrent concern of creating highly intuitive gestures and tasks

to assist with initiating the interaction, particularly in performative and allotted interfaces. By enabling keen participants to step onto the stage and start performing almost subconsciously, intuitive gestures reduce the risk of participants feeling embarrassed by making silly mistakes in public. As described in the continuum for intuitive interaction developed by the IUUI research group, great part of human behaviour when making sense of the surrounding world is innate, acquired at the very early stages of development and often manifested as reflexes and instinctive behaviour (Blackler and Hurtienne, 2007). Although Blackler *et al.* would refrain from classifying (as the IUUI does) this sort of innate reflexes not based on learned knowledge as *intuitive*, both groups nonetheless agree that those can indeed contribute for intuitive interaction. Interactive strategies making use of physical affordances also explore behaviour that is largely automatic and subconscious, implying obvious uses out of physical constraints of the interface. Interactions in public space that rely on innate reflexes and physical affordances can therefore reduce the risk of public embarrassment, since the actions implied by them are perceived by outside observers as being nothing other than 'normal' behaviour.

At the same time, it can also be argued that the very 'stage-like' nature of performative and allotted urban settings may minimize the need for employing intuitive gestures after the interaction starts: spectators are by then able to learn on the spot from the performers interacting with the system by simply observing them using the public interface. In fact, studies in the field (Bedwell and Caruana, 2012) have suggested that observing non-experts interacting can help to encourage people to join in the interaction. Compared with performative interfaces, however, allotted settings usually promote higher participation levels, both in absolute numbers and in length of the interaction. A larger interface not only accommodates a larger number of simultaneous participants but, by spreading the focus of the performance through the broader environment, they too also pose a smaller risk of individual social embarrassment. Likewise, the presence of many people simultaneously interacting creates de-facto demonstrators of how the interface is meant to be used. Familiarity with the interactive environment is therefore quickly gained through peer observation, making it more intuitive through the on-the-spot acquisition of expertise, the most specific level of acquired knowledge category on the intuitive interaction continuum proposed by the IUUI research group (Blackler and Hurtienne, 2007).

3.2. Intuitive interaction principles applied to public spaces

As discussed in Section 1, Blackler *et al.* (2006) proposed three design principles for supporting intuitive interaction: (1) use of familiar elements from the same domain for features that are already known; (2) use of familiar elements from related domains (including metaphors) for features that are less obvious and (3) internal consistency and redundancy. In this section, we contrast the case studies and interactive scenarios presented above to the principles proposed by their framework in order to derive recommendations specific to the design of interactive public spaces.

Despite intensive recent research and a growing body of urban interventions motivated by artistic and entertainment agendas, interactive public spaces are still perceived as an emerging platform. The seemingly limited range of standards available in the field limits the availability of familiar features (Principle 1 in the continuum developed by Blackler and Hurtienne (2007) and Blackler *et al.* (2006)) in the development of new interfaces for those scenarios. Mechanisms adopted in the design of intuitive interaction often rely on population stereotypes (cultural conventions ingrained from very early age) and—given the general predominance of full body gestures—physical affordances. Some of the metaphors employed, such as mirror-like interfaces, constitute in fact a compelling strategy in the design for intuitive interaction. Those will be discussed in the next paragraph. Performative interfaces in public space make use of familiar features (Principle 1) by employing, for example, mechanisms of engagement that have been recurrently used in other full-body interfaces, such as some types of videogames based on so-called NUIs, like those developed for the Microsoft Kinect. When presented to such interfaces, people used to playing full-body gesture-based videogames will stand in front of the interface (generally an electronic display) and raise or wave their arms expecting them to be matched by a corresponding graphical element on the screen (Ackad *et al.*, 2013). Likewise, some allotted interfaces will suggest the use of mobile devices for interaction with the display or media façade in lieu of videogame controlling devices or TV remote controls (Wiethoff and Gehring, 2012), since most people nowadays would be familiar with the latter, at least. This naturally poses a problem for those individuals not familiar with videogame playing or with using mobile devices beyond their regular scope of applications running on the devices themselves.

Far more common, however, is having designers resorting to metaphors and familiar features borrowed from other domains to illustrate the *modus operandi* of their proposed new interfaces (Principle 2). Schönböck *et al.* (2008) investigated the effectiveness of mirror-like interfaces to attract people's attention to an electronic display. Building from their work, Müller *et al.* (2010) described the concept of mirrors as one of the four prevailing mental models adopted by people when interacting with public displays (the other three being *posters*, *windows* and *overlays*). In fact, mirror-like interfaces constitute a very powerful strategy for intuitive interaction, since knowledge about how to deal with them is shared by most humans and acquired at very early stages of an individual development: it is both innate (driven by reflexes and instinctive behaviour) as well as sensorimotor (people 'naturally' know how to engage in interaction with their own reflected image, having knowledge of reflective surfaces such a glass and mirrors from a very early age). In both continua of interactive interaction

described above, interface elements with such a character are suggested to be highly intuitive.

The framework developed by Blackler *et al.* posits that physical affordances are one of the most effective drivers of intuitive interaction, for implying a knowledge that is inherent to possessing a human body. Likewise, according to the framework proposed by the IUUI (Blackler and Hurtienne, 2007), how to approach such physical affordances is driven by sensorimotor knowledge which is innate to human beings, manifested subconsciously and automatically: interaction unfolds effortlessly. Figure 1 illustrates the correspondence between those concepts in the context of the two continua. Mueller *et al.* (2010) also pointed out that borrowing such familiar physical affordances and metaphors from other fields and using them in a 'magical' context within the digital environment constitutes another very effective approach for sparking public interest: people are able to engage in the interaction immediately, but their otherwise ordinary actions suddenly appear extraordinary. They are encouraged to carry on with the interaction, among other factors, by getting rewarded with the feeling of being temporarily granted special powers. Crucial to the experience, though, is the fact that such powers feel intuitive. This has, in fact, been observed in *Liquid Light* (Hespanhol *et al.*, 2011; Hespanhol and Tomitsch, 2012, 2014), *Aarhus By Light* (Brynskov *et al.*, 2009) and *Solstice LAMP* (Hespanhol *et al.*, 2013, 2014b)—where participants interacted with their silhouettes reflected by the interface—as well as in *Body Movies* (Lozano-Hemmer, 2001)—where a body reflector (shadow playing) underpinned the intuitiveness of the proposed interaction between people and their projections on the building façade. Both *Solstice LAMP* and *Body Movies* can also be said to have extended the mirror metaphor by overlaying (Mueller *et al.*, 2010) people's 'shadows' with extra visual imagery, so that participants felt like exploring the interface further by the highly intuitive act of moving their bodies around. In regards to Principle 3, we observe that, in those works, consistency within the interface is generally ensured by (i) the strong preference for having visual elements driving the interaction, (ii) simplicity of movements allowed for them (e.g. people's silhouettes or shadows) and (iii) equal behaviour for such elements at any point within the interface. For example, in the interactions based on silhouettes or shadows, the users cannot do much more than use them as projections of the movements they enact in real-time with their own physical bodies. Such constraints, rather than limiting the scope of interaction, allow it to be kept simple and direct enough to be perceived as familiar (sensorimotor knowledge) and therefore learned intuitively by the majority of people coming across them.

Besides providing a low barrier to entry the interactive engagement by a wide range of participant profiles, keeping the basic interaction mechanisms for digital public environments close to body reflectors, physical affordances and sensorimotor knowledge has also been observed to yield an additional positive outcome: *creative engagement*. According to Edmonds *et al.* (2006), three types of aesthetic elements define creative engagement: attractors (those responsible for gaining attention of people), sustainers (those which maintain the attention gained) and relaters (those which spread the attention further). A spontaneous anecdotal feedback gained from multiple participants during execution of *Solstice LAMP*, for example, was that moving through the space over the floor projections resembled 'walking on shallow water'—something that we had never intended when designing it. In fact, it was not uncommon to observe participants hopping across the space or slightly kicking the projections around their feet as part of the interaction, which in turn at times triggered social interaction among participants. It can therefore be argued that in that particular scenario, physical affordances not only contribute as attractors to the interaction but also as sustainers and occasionally also relaters. Likewise, the direct feedback given to participants through their shadows in *Body Movies* prompted them to creative expression and social interaction with other participants in the space, sustaining the engagement for longer (Fischer and Hornecker, 2012).

While immediate feedback mapped directly to body movements enhances the perception of control over the interface in performative and allotted settings, in responsive ambient interfaces the goal is generally the opposite: to respond to the crowd participation without inviting people to actively engage in interaction with the interface. In terms of interaction design, such concerns often get translated as minimization of physical affordances (Figs. 2 and 3), with feedback not only spatially scattered around the whole environment, but also delayed in relation to the actions that may have originally triggered it. From the participants perspective, the causes for responses from the interface become therefore way less clear. Familiarity with similar conditions thus leads to the perception of control being beyond their immediate reach. *Chromapollination* (Hespanhol and Tomitsch, 2014), for example, appealed to Principle 1 by creating an enclosed environment where subtle changes in the light condition occurred around participants but only a few seconds after being triggered by their movements in the space, as if they were unfolding by themselves. In that regard, the metaphor of wind hitting the sculptural flowers (Principle 2) helped to reinforce the low sense of control over the environmental responses. Finally, the responses were somewhat abstract, limited to the ambient colour changes and occurred in an equivalent manner in the three corners of the space. That ensured both internal consistency and redundancy (Principle 3), also manifested by the fact that the change in the flowers colours matched that of the 'light pollen' carried through the LED ceiling. Passers-by were not invited to attempt interaction with any specific spot within the environment.

The types of modality used for feedback can also influence how people interpret the interface based on their intuition. For example, in full-body gesture-based interfaces a *dwelling* visual feedback seems to be favoured for indicating upcoming events associated to user actions. Such a modality of feedback

indicates progress towards an occurrence as long as a participant holds their position, and may be expressed, for instance, as a progressively filled circle around an icon being selected (Hespanhol *et al.*, 2012; Microsoft Corporation, 2013). The reason for that is likely due to technology familiarity: similar mechanisms for progress indication have been largely employed in websites and mobile applications for many years with the purpose of giving users enough time to realize what is about to happen and correct their course of action in case of accidental activation. Likewise for cueing or warning about events affecting the environment as a whole (rather than specific individuals), particular forms of audio feedback—such as increasingly higher frequencies or faster beats—have proved to be more effective, as was the case of a study performed on *Solstice LAMP*'s interface (Hespanhol *et al.*, 2013). This is also highly intuitive for bearing strong parallels to similar real-world situations, such as fire alarms, emergency sirens and public announcement systems, where sound effects are played to address everybody within a certain locality about an upcoming occurrence. In terms of the interactive scenarios presented, such mechanisms would be more suitable for allotted and performative interfaces.

In this section, we presented arguments supporting intuitive interaction in public spaces, as well as how the principles from the intuitive interaction continua found in the literature can inform the design of interfaces for public interaction. In the next section, we extend such a discussion by presenting feedback strategies that can, by design, frame the intuitiveness of a public space in different ways.

4. DESIGNING FOR INTUITIVENESS

The discussion above points towards strategies for structuring feedback that can assist intuitive interactions in public urban spaces. As we have mentioned earlier in this paper, research by Antle *et al.* (2009) points to the significance of perceivable feedback in the construction of input actions interpreted as intuitive. Core concerns underpinning the design of interactive experiences in urban spaces include: (i) to give clear feedback about who is in control of the interface at any given time; (ii) to clearly indicate what each participant is in control of and (iii) to analyse the identities assumed by people participating in the interaction as opposed to those observing from outside the interactive zones. Strategies for structuring feedback should therefore be considered in respect to (i) the physical layout of the public space it will be installed at and (ii) the social context it is being designed for. Such factors are important because they help to determine the available physical dimensions (and consequently affordances) of the interactive interface, how it dialogues with the surrounding urban architecture, the amount of potential participants, the nature of the content displayed and, consequently, the type of interactive public space (performative, allotted or responsive ambient).

Feedback strategies that emerged from the presented types of public spaces are: directional feedback versus scattered feedback; immediate and concrete feedback versus delayed and abstract feedback and visual feedback versus audio feedback.

4.1. Directional versus scattered feedback

Directional feedback is the mechanism whereby some interfaces yield clear and unambiguous responses to specific participants, creating the illusion of a strong mapping between physical movements (enacted with their bodies or remotely with mobile devices) and their digital counterparts. As a consequence, such digital representations are also intuitively mapped to each participant's personal space, thus being effectively perceived as extensions of their physical bodies.

Allotted and responsive ambient interfaces, being capable of accommodating a larger number of simultaneous participants, naturally respond to those at various different locations at the same time. In accordance with Principle 3 (internal consistency) in Blackler *et al.*'s (2006) framework, participants should be able to interact with the environment equally wherever they decide to do so within the wide interactive zone, with responsive features uniformly distributed across the interface. Communication about the overall state of the environment ends up being targeted to observers outside of the zone, who can appreciate the 'big picture' conveyed by the broader space. For example, in allotted interfaces, the feedback is scattered at the level of the whole environment; however, directional for each individual participant, who can clearly and unequivocally make sense of their input. Ambient interfaces, on the other hand, appear to evolve independently of participants, even when they are, in fact, responding to their input. For the latter to work effectively, people should therefore be kept oblivious of their level of participation, with little or no direct feedback provided in that regard.

4.2. Immediate and concrete versus delayed and abstract feedback

Coupled to the notion of directional feedback discussed above, interfaces that are highly responsive and issue feedback immediately after an action performed by the participant contribute to the notion of control over the interface. Intuitively, participants interpret the feedback as a consequence of their acts. Contrarily to immediate feedback, a delayed response relaxes the perception of control over the interface—and, consequently, responsibility over the content generated. This is a feature particularly sought by ambient interfaces (e.g. *Chromapollination* (Hespanhol and Tomitsch, 2014)), which seeks to avoid synchronous interaction.

Worthy of note is that the level of abstractness in the feedback is also often associated with its immediacy. Immediate feedback is often concrete and meaningful to the participant (e.g. silhouettes and shadows), while also contributing to an

increased sense of agency. Delayed feedback, in turn, holds a more abstract nature (e.g. change of colours, ambient sounds and lighting conditions), causing the participant to feel little responsibility over the interactive interface behaviour.

4.3. Visual versus audio feedback

Arguably, visual and audio are the two main modalities employed by interactive applications in general. In the particular field of interactive public spaces, visual feedback seems to be largely preferred for direct and immediate responses, making it the tool of choice for digital representation of individuals (Brynskov *et al.*, 2009; Hespanhol *et al.*, 2011; Hespanhol and Tomitsch, 2014; Jacucci *et al.*, 2010; Lozano-Hemmer, 2001; Mueller *et al.*, 2012; Wiethoff and Gehring, 2012). It is also the most effective modality for indication of progress regarding commands (e.g. selection) issued by the participants (Hespanhol *et al.*, 2012; Microsoft Corporation, 2013).

Studies have indicated that audio feedback, on the other hand, can be more effective as cueing mechanisms for upcoming events affecting the whole crowd in a space (Hespanhol *et al.*, 2013). This is largely due to the nature of each modality: not everybody can see every section of the environment, but a sound played loud enough will be heard by all participants and intuitively interpreted as a general alert. Such inherent intuitiveness of distinctive audio feedback can be traced to population stereotypes (Blackler *et al.*, 2006), given that similar audio mechanisms have been traditionally used to catch people's attention towards an upcoming event (e.g. fire alarms). Generally speaking, however, audio feedback addresses our very innate behaviour, closely related to 'reflexes, e.g. the startle response: an involuntary reaction to a sudden unexpected stimulus (especially a loud noise) which involves flexion of most skeletal muscles and a variety of visceral reactions' (Blackler and Hurtienne, 2007). Naturally, a lot of audio feedback can also be disruptive and confusing in a public space; for that reason, cueing and warning sounds must be easily distinguishable from other ambient noise. Moreover, cueing and warning sounds must also be easily distinguishable from each other (e.g. audio used to indicate a green pedestrian crossing must be remarkably different from that adopted for fire alarms).

It is important to point out that such strategies are not comprehensive. We sought to select case studies that are representative of common types of interactive public spaces, which mostly resort to audio-visual effects for giving feedback to the user. There are, of course, other modalities that can be potentially used for feedback—such as touch, for instance—that have not been covered by the present analysis. Also the identified strategies are not mutually exclusive—rather, they refer to particular trade-offs on how feedback is given to the public and the purpose of providing such feedback. For example, performative public spaces generally make large use of feedback mechanisms that are directional, immediate and predominantly visual. In contrast, responsive ambient environments tend to favour scattered and delayed visual feedback, coupled with audio cues or alerts when it is necessary to address the whole crowd at once. Allotted interfaces generally reflect performative design goals, although distributed over a larger interface; such larger scale, however, often causes them to occasionally employ ambient features, like the use of audio feedback to address environment-wide events.

This analysis can be further elaborated by grouping the strategies described above with respect to their primary goals. For instance, interface elements (particularly visual ones) that are mapped directly to the movements of an individual's body tend to be taken as a literal representation of that person in the digital realm (body reflectors). Therefore, feedback being directed to individuals or scattered across the interface causes participants to perceive their identity within the interactive environment differently. Similarly, whether the feedback is immediate or delayed changes the perception of the extent participants can control what they can see or hear. Finally, if the purpose of the feedback is to respond to specific individuals, using visual elements will likely work more effectively; conversely, if the intention is to cue or warn about conditions that may affect the whole crowd, then audio effects would be more recommended, given the pervasiveness of sound and its visceral appeal.

Based on this analysis we therefore suggest three dimensions, each with two opposite strategies to achieve the design goal: *identity*; *control* and *scope*. *Identity* refers to how much the feedback is associated with a specific individual: *directional feedback* therefore delimits an individual control zone, while *scattered feedback* promotes equality among participants. *Control* refers to how immediately an action from an individual is perceived to cause as a consequence a clear impact on the interface: on one hand, *immediate and concrete visual effects* convey a strong agency; *delayed and abstract feedback*, on the other hand, indicate weak or absent agency. Finally, *scope* refers to the use of different media modalities to promote individual or collective awareness: *visual feedback* for individually driven actions; *audio effects* for cueing environment-wide events. Figure 7 illustrates the identified strategies, their corresponding design goals, and how their utilization would contribute for the intuitive perception of the space interactive nature by passers-by and participants. It consists of a matrix mapping the three design goals we previously identified—*identity*, *control* and *scope*—to the three types of interactive public space discussed—*performative*, *allotted* or *responsive ambient*. Each cell in the matrix indicates the type and level of feedback we have identified as ideal to promote intuitive interaction on each of the scenarios.

As discussed in the previous section, some interactive public spaces clearly favour particular strategies—in fact, we would argue that to a large extent it is the very utilization of such strategies that forges the interactive space as being of one type or another. For example, if the interaction is designed around directional feedback immediately mapped to people's

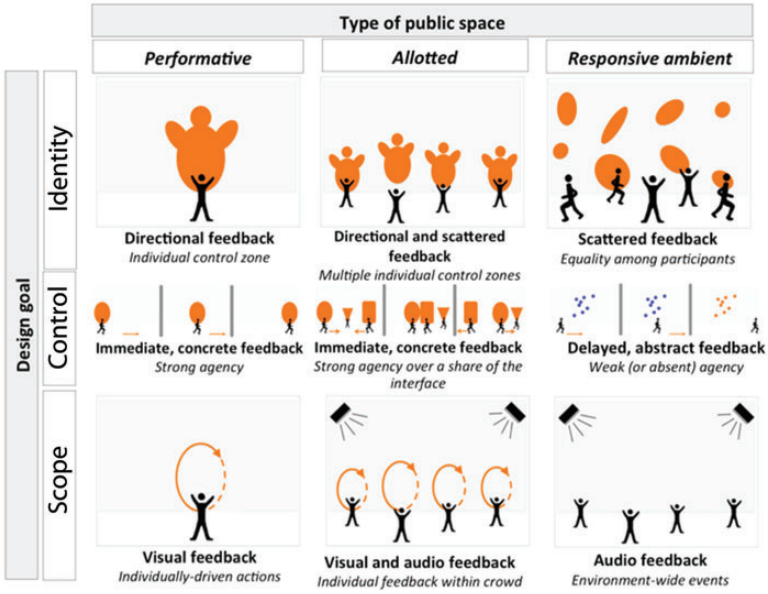

Figure 7. Feedback strategies for intuitive interaction in public spaces.

Table 2. Feedback strategies mapped to type of feature familiarity and knowledge levels.

Type of public space	Design goal	Feature familiarity (Blackler *et al.* continuum)	Knowledge level (IUUI continuum)
Performative	Identity	Body reflector	Sensorimotor
	Control	Body reflector	Sensorimotor
	Scope	Population stereotype	Sensorimotor/culture
Allotted	Identity	Body reflector	Sensorimotor
	Control	Body reflector	Sensorimotor
	Scope	Familiar feature from other domain	Culture
Responsive ambient	Identity	Population stereotype	Culture
	Control	Population stereotype	Sensorimotor/culture
	Scope	Familiar feature from other domain	Culture

body movements and predominantly visual, the responsive environment is likely to be intuitively perceived by the crowd as performative. This is a direct consequence of the high utilization of physical affordances (or body reflectors) (Blackler and Hurtienne, 2007) in the full-body interaction design. On the other end of the scale, if the feedback is scattered through the space, delayed in relation to people's body movements, abstract in nature and largely audio-based, the environment is likely to be intuitively interpreted as ambient, albeit responsive. The abstract nature of the latter also encourages visual and audio feedback drawn from cultural conventions (familiar features from the same or other environments, as well as metaphors) to highlight intuitiveness. Table 2 maps each scenario to the type of feature familiarity and knowledge levels as presented in the intuitive interaction continua developed by Blacler *et al.* and the IUUI research group, respectively. It is precisely the balance in the utilization of each of the feedback strategies that will ultimately tip the intuitive perception of an interactive public space towards either the performative or ambient extremes; likewise, an even balanced distribution of all feedback strategies will result in an interface intuitively perceived as allotted by participants, with feedback scattered at the level of the whole environment (a feature of responsive ambient interfaces); however, directional at the level of each individual participant (as typical of performative interfaces).

As a consequence, designers starting a new interactive urban space project should consider where their brief sits in regards to each of the design goals displayed in Fig. 7 (i.e. how much emphasis on the individuals as opposed to the broader environment). That will, in turn, determine the type of interactive environment they should design to match their audiences' expectations so that, when people approach those environments, the interaction can unfold intuitively. For example, if the concept prescribes individually driven actions, high sense of agency over the interface and a strongly perceived identification with particular media artefacts in the environment,

a performative interface should be considered. That, in turn, will have impacts on the spatial distribution of technology over the architecture for guiding the crowd movement towards that goal (e.g. a central interactive display, delimiting a clear stage area). Conversely, if the opposite is expected, an emphasis to audio should be given and the feedback mechanisms should be scattered across the environment as well as delayed in relation to movements from the crowd.

5. CONCLUSION

In this article, we discussed the design of intuitive interactions in the emerging area of interactive public spaces. Based on the analysis of works deployed on urban environments in the past few years, we established a general classification of interactive public spaces as *performative*, *allotted* or *responsive ambient*, depending on the level of public participation encouraged by them as well as the roles assumed by participants while engaged with the interface. Each scenario feeds different levels of expectations from people towards the environment, leading to distinct forms of crowd self-organization and social interaction.

We then used the framework for intuitive interaction proposed by Blackler *et al.* (2006) to analyse such interactive scenarios—which, for being solely based on tracking of body movements as input mechanism, are often labelled *NUIs*. Our aim was to understand the core elements contributing to the perception of 'naturality' (or lack thereof) experienced by participants engaging with such interfaces. From our analysis, we derived six strategies (grouped in three opposing pairs) for assisting the design of intuitive interactions in interactive public spaces: *directional feedback* versus *scattered feedback*; *immediate feedback* versus *delayed feedback* and *visual feedback* versus *audio feedback*. We discussed the main purpose of each of them and how they can be used more effectively to promote different particular forms of public behaviour. Although by no means comprehensive, the presented list of strategies for intuitive interaction with digitally augmented public spaces points forward to two potential design outcomes: (i) what factors to address for encouraging highly intuitive interaction when designing for performative, allotted or responsive ambient interfaces and (ii) what settings to fine tune in order to achieve dynamic transitions between environments.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *www.iwc.oxfordjournals.org*. It consists of videos exemplifying some of the works mentioned in the manuscript, namely *Liquid Light*, *Solstice LAMP* and *Chromapollination*.

ACKNOWLEDGEMENTS

Liquid Light and *Chromapollination* were developed at the Design Lab—Faculty of Architecture, Design and Planning—University of Sydney, in collaboration with both academics and postgraduate students. In addition, Chromapollination was promoted by Destination NSW and Vivid Sydney. *Solstice LAMP* was promoted by Destination NSW, Vivid Sydney and the Amplify Festival as collaboration between researchers from the Design Lab and the Sydney Conservatorium of Music. We acknowledge the cross-disciplinary teams that made such works possible.

FUNDING

This work received no grant from any funding agency in the public, commercial or not-for-profit sectors. Financial support for each individual project cited in the manuscript, if existent, was received through funding processes unrelated to this particular work.

REFERENCES

Ackad, C., Wasinger, R., Gluga, R., Kay, J. and Tomitsch, M. (2013) Measuring Interactivity at an Interactive Public Information Display. Paper Presented at the OzCHI'13, Adelaide, Australia.

Acton, L. (2011) Allotment Gardens: A Reflection of History, Heritage, Community and Self. Papers from the Inst., of Archaeology, 21, 46–58.

Antle, A.N., Corness, G. and Droumeva, M. (2009) Human–computer-intuition? Exploring the cognitive basis for intuition in embodied interaction. Int. J. Arts Technol., 2, 235–254.

Bedwell, B. and Caruana, T. (2012) Encouraging Spectacle to Create Self-Sustaining Interactions at Public Displays. Paper Presented at the PerDis'12, Porto, Portugal.

Blackler, A. and Hurtienne, J. (2007) Towards a unified view of intuitive interaction: definitions, models and tools across the world. MMI-Interakt., 13, 37–55.

Blackler, A., Popovic, V. and Mahar, D.P. (2006) Towards a Design Methodology for Applying Intuitive Interaction. Paper Presented at the WonderGround: 2006 Design Research Society Int. Conf., Lisbon, Portugal.

Bødker, S. (2006) When Second Wave HCI Meets Third Wave Challenges. Paper Presented at NordiCHI'06, Oslo, Norway.

Brignull, H. and Rogers, Y. (2003) Enticing People to Interact with Large Public Displays in Public Spaces. Paper Presented at the INTERACT'03, Zurich, Switzerland.

Brynskov, M., Dalsgaard, P., Ebsen, T., Fritsch, J., Halskov, K. and Nielsen, R. (2009) Staging Urban Interactions with Media Facades. Paper Presented at the INTERACT'09, Uppsala, Sweden.

Bush, D.J. (1989) Body Icons and Product Semantics. Paper Presented at the Semantic Visions in Design, Helsinki, Finland.

Cook, I. and Laing, M. (2011) Visibility and the policing of public space. Geography Compass, 5, 610–622.

Dalsgaard, P. and Halskov, K. (2009) Dynamically Transparent Window. Paper Presented at the CHI EA'09, New York, NY, USA.

Dalsgaard, P. and Halskov, K. (2010) Designing Urban Media Façades: Cases and Challenges. Paper Presented at the CHI 2010, Atlanta, GA, USA.

Edmonds, E.A., Muller, L. and Connell, M. (2006) On creative engagement. Vis. Commun., 5, 307–322.

Fischer, P.T. and Hornecker, E. (2012) Urban HCI: Spatial Aspects in the Design of Shared Encounters for Media Façades. Paper Presented at the CHI'12, Austin, TX, USA.

Goffman, E. (1963) Behaviour in Public Places, Notes on the Social Organisation of Gatherings. The Free Press, New York, NY, USA.

Goffman, E. (1973) The Presentation of Self in Everyday Life. The Overlook Press, Woodstock, New York, NY, USA.

Hall, E.T. (1966) The Hidden Dimension. Doubleday, Garden City, NY, USA.

Hespanhol, L., Bown, O., Cao, J. and Tomitsch, M. (2013) Evaluating the Effectiveness of Audio-Visual Cues in Immersive User Interfaces. Paper Presented at the OzCHI'13, Adelaide, SA, Australia.

Hespanhol, L., Sogono, M.C., Wu, G., Saunders, R. and Tomitsch, M. (2011) Elastic Experiences: Designing Adaptive Interaction for Individuals and Crowds in the Public Space. Paper Presented at the OzCHI'11, Canberra, Australia.

Hespanhol, L. and Tomitsch, M. (2012) Designing for Collective Participation with Media Installations in Public Spaces. Paper Presented at the Media Architecture Biennale 2012, Aarhus, Denmark.

Hespanhol, L. and Tomitsch, M. (2014). Understanding the effects of contextual constraints on performative behaviour in interactive media installations. Pers. Ubiquitous Comput., 18, 1651–1665

Hespanhol, L., Tomitsch, M., Ackad, C. and Kay, J. (2014a). Icebreaker NUIs: Starting Social Conversations Around Interactive Urban Spaces. Paper Presented at the DIS'14, Vancouver, BC, Canada.

Hespanhol, L., Tomitsch, M., Bown, O. and Young, M. (2014b). Using Embodied Audio-Visual Interaction to Promote Social Encounters Around Large Media Façades. Paper Presented at the DIS'14, Vancouver, BC, Canada.

Hespanhol, L., Tomitsch, M., Grace, K., Collins, A. and Kay, J. (2012). Investigating Intuitiveness and Effectiveness of Gestures for Free Spatial Interaction with Large Displays. Paper Presented at the PerDis'12, Porto, Portugal.

Hurtienne, J. and Blessing, L. (2007) Design for Intuitive Use—Testing Image Schema Theory for User Interface Design. Paper Presented at the 16th Int. Conf. Engineering Design, Paris, France.

Hurtienne, J. and Israel, J.H. (2007) Image Schemas and their Metaphorical Extensions—Intuitive Patterns for Tangible Interaction. Paper Presented at the TEI'07, New York, NY, USA.

Jacucci, G., Morrison, A., Richard, G.T., Kleimola, J., Peltonen, P., Parisi, L. and Laitinen, T. (2010) Worlds of Information: Designing for Engagement at a Public Multi-touch Display. Paper Presented at the CHI'10, Atlanta, GA, USA.

Kray, C., Galani, A. and Rohs, M. (2008) Facilitating Opportunistic Interaction with Ambient Displays. Paper Presented at the CHI'08, April 5–10, Florence, Italy.

Lakoff, G. and Johnson, M. (1980) Metaphors We Live By. Chicago Press, Chicago, IL.

Lino, J.A., Salem, B. and Rauterberg, M. (2010) Responsive environments: user experiences for ambient intelligence. J. Ambient Intell. Smart Environ., 2, 347–367.

Lozano-Hemmer, R. (2001) Body movies. relational architecture 6. http://www.lozano-hemmer.com/body_movies.php (accessed February 20, 2014).

Ludvigsen, M. (2005) Designing for Social Use in Public Places—a Conceptual Framework of Social Interaction. Paper Presented at the DPPI'05, Eindhoven, The Netherlands.

Malone, T.W. (1981) Toward a theory of intrinsically motivating instruction. Cogn. Sci., 4, 333–369.

Memarovic, N., Langheinrich, M., Alt, F., Elhart, I., Hosio, S. and Rubegni, E. (2012) Using Public Displays to Stimulate Passive Engagement, Active Engagement, and Discovery in Public Spaces. Paper Presented at the MAB'12, Aarhus, Denmark.

Microsoft Corporation (Producer). (2013). Kinect for windows—human interface guidelines. Version 1.8. Retrieved from http://go.microsoft.com/fwlink/?LinkID=247735 (accessed March 10, 2013).

Mueller, J., Alt, F., Schmidt, A. and Michelis, D. (2010) Requirements and Design Space for Interactive Public Displays. Paper Presented at the MM'10, Firenze, Italy.

Mueller, J., Walter, R., Bailly, G., Nischt, M. and Alt, F. (2012). Looking Glass: A Field Study on Noticing Interactivity of a Shop Window. Paper Presented at the CHI'12, Austin, TX, USA.

Norman, D. (1993). Things That Make Us Smart. Basic Books, New York, NY.

Norman, D. (2004) Affordances and design. http://www.jnd.org/dn.mss/affordances_and_desi.html (accessed August 25, 2014).

Ojala, T., Kostakos, V., Kukka, H., Heikkinen, T., Lindén, T., Jurmu, M., Hosio, S., Kruger, F. and Zanni, D. (2012). Multipurpose Interactive Public Displays in the Wild: Three Years Later. Computing Now, 45, 42–49.

Rico, J., Jacucci, G., Reeves, S., Hansen, L.K. and Brewster, S. (2010) Designing for Performative Interactions in Public Spaces. Paper Presented at the UbiComp'10, Copenhagen, Denmark.

Schönböck, J., König, F., Kotsis, G., Gruber, D., Zaim, E. and Schmidt, A. (2008). MirrorBoard—An Interactive Billboard. Paper Presented at Mensch und Computer 2008, Lübeck, Germany.

Tomitsch, M., Ackad, C., Dawson, O., Hespanhol, L. and Kay, J. (2014) Who Cares About the Content? An Analysis of Playful Behaviour at a Public Display. Paper Presented at the PerDis '14, Copenhagen, Denmark.

Valkanova, N., Walter, R., Vande Moere, A. and Müller, J. (2014). MyPosition: Sparking Civic Discourse by a Public Interactive Poll Visualization. Paper Presented at the CSCW'14, Baltimore, MD, USA.

Wiethoff, A. and Gehring, S. (2012). Designing Interaction with Media Façades: A Case Study. Paper Presented at the DIS'12, Newcastle, UK.