Medium-specific properties of urban screens : Towards an ontological framework for digital public displays

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ABSTRACT
The purpose of the present theoretical exploration is to lay the foundations of a platform-specific ontology of *urban screens*, which we define as an architectural scale media environment comprising two or more digital displays that can support interactive and/or artificial intelligence features. Still in its budding stages, this framework is intended to assist artists and HCI practitioners in the conception and evaluation of public space installations that heavily rely on digital displays. Using an architectural approach that analyzes urban screens in terms of medium specificity, this paper asks: "What are some of the key ontological attributes of urban screens as a computational medium?" We propose a taxonomy of five medium-specific properties articulated in relation to sensory modalities and modes of interaction. In providing an aesthetic, poetic, cognitive and experiential basis for understanding urban screens, this paper seeks to help researchers broadly consider their design parameters and generate new ideas.

Author Keywords
Interactive public displays; architectural approach; medium specificity; sensory modalities; modes of interaction; ontological framework; media architecture.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; J.5 Arts and humanities: fine arts.

General Terms
Design; Human Factors; Theory.

INTRODUCTION
Known generically as digital public displays, media façades and large LED, LCD and plasma screens are gradually becoming ubiquitous in urban environments. They can be *static*, functioning as digital media placards with still, unchanging content (text or images) as we see with electronic signage on roadsides, contextual maps inside buildings or certain advertising billboards. They can also be *dynamic*, as when displays showcase videos or animated artistic works; automatically cycle through content; or when data is periodically updated as seen on public notice boards.

In Europe, the term *Urban Screens* primarily refers to a social movement that promotes the appropriation of digital public displays in urban space for the purposes of community building and artistic creation [37]. In this paper, however, we use the term *urban screens* more broadly to describe a public space in the built world that includes two or more digital displays with no particular distinction made in relation to their purpose or location. In addition, we construe urban screens as a networked system of displays that can support interactivity and artificial intelligence.

The purpose of this exploratory paper is to outline a platform-specific ontology of urban screens that will provide artists and researchers with an aesthetic, poetic, cognitive and experiential basis for the design and evaluation of architectural scale computationally-operated media environments which include two or more digital displays that can support interactivity. In asking, "What are some of the key ontological attributes of urban screens as a computational medium?", this paper aims to identify some of the essential characteristics and dimensions of digital displays when they are deployed in actual public space.

Our object of study is peculiar in that it is a physical environment in which users not only interact with people and technology, but also, amongst other things, with artifacts, buildings, empty spaces, changing atmospheric conditions and of course, human bodies in motion. Given that in urban screens, users simultaneously experience interfaciality with such a great diversity of elements, we have adopted an architectural approach that draws on medium specificity, a fine arts concept foreign to HCI. We thus investigate the aesthetic properties of urban screens as determining factors of interaction and sensory experience.

This paper is divided into three sections. First, we give an overview of related work concerned with conceptual frameworks for digital displays. Next, we describe our methodological approach. Finally, we describe the space used for our observational analyses and then articulate each medium-specific property by relating it to sensory modalities and existing or proposed modes of interaction.

C&C '13, June 17 - 20 2013, Sydney, NSW, Australia
 ACM 978-1-4503-2150-1/13/06…$15.00.

RELATED WORK

To the best of our knowledge, no attempt has been made to develop an ontological framework for environments with digital public displays. In the past decade, a few works have proposed conceptual frameworks which either focus on heuristics, or else study spatial factors or social interaction.

In 2003, Mankoff et al. published a set of ten heuristics that could be used to evaluate the effectiveness of digital public displays [22]. These included "peripherality of display", "aesthetic and pleasing design" and "easy transition to more in-depth information". These heuristics informed aesthetic concerns, but did not constitute a conceptual framework.

Churchill et al. [3] designed large interactive digital displays that could be used to post, share and annotate information in a work environment. During the deployment of their PLASMA POSTERS, they identified three sets of factors which included four forms of engagement with content. This framework mainly supports social computing.

Similarly, Huang has made several contributions by investigating issues of awareness in relation to digital public displays. Her frameworks mainly explore heuristics [15] or context-awareness [14]. Vande Moere and Wouters also proposed a framework to analyze context-awareness in media architecture but with a lens on social values [40].

In their study of how users interact with large interactive public displays, Brignull and Rogers identified three distinct "activity spaces" hinging on the user's orientation with, and distance from, the display [2]. Although, their public interaction flow model provides a framework that bridges social and spatial factors, it ignores aesthetics. Similarly, Vogel and Balakrishnan's interaction framework for public ambient displays describes four continuous phases (zones), which each support different forms of interaction based on a user's distance from a digital vertical surface [42]. Key features of this framework are that it enables interaction with multiple users and emphasizes fluid transitions between different phases. However, it is only concerned with the engineering of location awareness.

Greenberg's proxemics interaction framework is the conceptual model that appears to be most closely related to our own research [13]. Although their framework is device-driven with a focus on spatial relationships, it is articulated on an ecological approach that explores the complex interplay between people, devices and non-digital objects.

Some practitioners have drawn on aesthetics to develop interaction paradigms that can be applied to displays. For instance, Mueller's *exertion interfaces* come with a framework that seeks to create physically engaging experiences with technology [25]. Other designers have worked on frameworks for interaction which consider crossmodal interaction [30, 35], kinesthetic interaction [8, 36] or the performative aspects of interaction with technology [32, 36]. These interaction paradigms have all informed our ontological framework for urban screens.

METHODOLOGY

Rather than place the emphasis on social interaction or spatial configuration, this paper proposes to tailor a holistic approach for thinking about urban screens in public space. Like some of the extant work that has studied digital displays, our framework is largely inspired by theories from Gibson's Ecological Psychology [10, 11]. However, instead of adopting a Gibsonian ecological approach as practiced in HCI, we have chosen to adopt an architectural approach that describes urban screens in terms of medium specificity.

Architectural approach

Considering our theoretical exploration is concerned with the aesthetics, poetics cognitive and experiential aspects of urban screens, we argue that this platform is best understood as an environment rather than as a space, place or locale primarily created by, and through social interaction [5]. Gibson has remarked that the difference between environment and space is that the former implies a point of observation *within*, as well as a degree of awareness of this position, whereas the latter does not [11].

This distinction Gibson makes between environment and space is an important one. The former takes into account a physical setting *and the awareness* of one's body in this environment. This allows us to construe urban screens as *propriospecific* in the sense that users are aware of their physical position as they stand or move inside the space of representation. Indeed, Gibson would say that "it specifies the body". By contrast, a platform that is *exterospecific* "specifies the world" [11]. We purport that proprioception is a determining factor in the *experience* of urban screens.

However, in HCI, the ecological approach has mostly been used to understand "how people interact with artifacts" by means of two of Gibson's conceptual tools: *ecological constraints* and *affordances* [34]. We have chosen not to use these concepts: first, because the way they are currently applied in technology design offers a narrow reading of Gibson which tends to limit interaction to what can be designed, not what can be experienced [16]; second, because it has been argued that the term affordances is too often used to mean "constraints" or "conventions", a derivation in meaning from Norman's "perceived affordances" [29]; and third, because in our view, the study of urban screens necessitates a methodological tool that can account for the fact that new phenomena and possibilities for interactions may emerge accidentally from variations in the environment itself, because it includes, amongst other things, other artifacts, buildings, empty spaces, changing atmospheric conditions and of course, bodies in motion. In public space, people inevitably interact with more than a technological device or application; thus interfaciality can simultaneously be experienced with many elements at once.

For this reason, we believe the study of urban screens in public space should be predicated on an architectural approach that places greater emphasis on the perceptual

experience of the setting at large in relation to its physical components. As we will see, construing urban screens as an architectural medium raises several new research questions. For instance, although an architectural approach recognizes that the experience of the built environment may be strongly mediated by vision, it is based on the assumption that perception of large-scale environments is primarily haptic, that is, dominated by tactile and proprioceptive sensations, because observers usually move through it [39].

To envision new design factors and interaction paradigms for urban screens, we need to ask what is the dynamic structure of this platform, that is, what is its ontological framework. This is our rationale for advocating the use of medium specificity in HCI. Our investigation of urban screens focuses on its aesthetic and spatial character rather than on the users' experience of it through designed affordances, for investigating the nature of a medium can allow artists to push its boundaries and open it to new uses.

Medium specificity

Medium specificity, one of the most influential art theory approaches of modernism, is a critical approach that evaluates the strength of an artwork in terms of the formal, stylistic, and mechanical qualities of a medium. Surprisingly, it has never been used in HCI research. Given its roots in the humanities tradition, it has remained a method of analysis mostly used to critically look at computational media works [19]. Yet the concept of medium specific properties has been a powerful one in the practice of art for over a century. In this sense, it can be said to have had a strong influence in fine and applied art.

Although similarities exist, medium specific properties are not to be confused with what the field of HCI calls affordances. There are substantial distinctions between the affordances of a technology and its medium specific properties. First, while the former is mainly concerned with perceived or real features that call the user to *action* (e.g. a button that performs a function), the latter identifies the attributes that make a technological platform a unique medium of *representation* (e.g. a button on a LED screen is made up of pixels). Second, while an affordance offers possibilities and constraints for action (e.g. small vs. large screen size), medium specificity relates to structure, thus the poetics of the medium (e.g. screens are an essential part of the medium). Third, while affordances are features that might be added or removed from a platform (e.g. optional geolocative tracking), medium specific properties are intrinsic to it (e.g. the platform *is* geolocative). Medium specificity echoes Gibson's *original* notion of affordances:

> …the affordance of anything is a specific combination of the properties of its substance and its surfaces taken with reference to an animal…an affordance is not bestowed upon an object by a need of an observer and by his act of perceiving it. The object offers what it does *because it is what it is* (italic emphasis added) [12].

As we understand it, the main difference between Gibson's notion of affordances and medium-specific properties is that the former is concerned with the *relationship* between the observer and the properties of the object (Gibson specifies: "properties…taken with reference to an animal"), whereas the latter places the focus on understanding what makes the medium *peculiar* as compared to other media. Both are concerned with the properties of an object, but affordances focus on the opportunities for actions that can emerge from this relationship rather than on the structural character of the medium/object itself. Affordances tells us how we can relate to something while medium specificity sets out to define what makes it what it is. We believe that exploring the ontology of urban screens might open up new ways of thinking about it, perhaps leading to new uses.

Ergo, this paper asks, if we construe urban screens as a computational medium in its own right, what are *its* medium specific properties? The following section outlines five medium specific properties that form the scaffolding of our ontological framework for urban screens: multiple screen modularity, propriospecificity, architectural lighting, motion and transduction. Given that our taxonomy emerged from our preliminary observations of real urban screens, we briefly describe this space before beginning our discussion.

MEDIUM SPECIFIC PROPERTIES OF URBAN SCREENS

Figure 1 shows a red-colored map that marks an area of one square-kilometer in the downtown core of Montréal, Canada. The white boxes represent different buildings simultaneously used as digital media façades at night to display a wide variety of art projects. These urban screens are part of a technological park in public space that operates year round with content changing on a periodical basis.

From most vantage points, these media façades can be seen only one at a time. However, an observer positioned at the emplacement marked by the characters X1 appearing in blue font on Figure 1 could arguably see two at the same time. If the projections on the two buildings identified as A and B are higher than the top of the dark-shaded buildings that separate them behind C, then an observer could arguably see three projections at once from corners X2 or X3, possibly four if the buildings between C and D are low.

Figure 1 - Bird's eye view of eight architectural scale digital displays located within a perimeter of one square-kilometer in downtown Montréal, Canada. ©2012QuartierdesSpectacles

Such a space represents many challenges from a design perspective. First, it poses the problem of how the different modules of a complex platform relate to, and/or influence, one another. Second, it can problematize the cognitive concept of presence in ways seldom studied in HCI design. Third, the sheer size of these dynamic digital displays causes the light and color they emit and reflect to become highly visible and pervasive in certain conditions. Fourth, the setup begs the question, what happens when the observer is set in motion in this public space augmented with digital displays of different sizes and positioning? Fifth, how does the digital blend with the material to enhance the interactive experience of urban screens? We now look at how each of these issues relates to a medium specific property, which in turn informs interaction design.

Multiple Screen Modularity, Spatial Montage, Paradigmatic Interaction

As a computational medium, urban screens offer the possibility of projecting on multiple screens situated in different locations in a real physical environment. One of these screens is necessarily of architectural scale while the rest may either consist of other large projections within the same environment, or else smaller screens on portable devices used to interact with the main public display(s).

Designing for distinct screen content in disparate parts of one's full field of vision is a problem unique to media architecture: portable devices offer a single screen too small to see several views; desktop computers have either multiple displays or else a screen size large enough to view more than one window, but in both cases, images exist side by side on what is, for all intents and purposes, an almost two-dimensional space; and virtual reality does offer a wide view on a screen, but it is only a simulation of a 3D space.

In this sense, the ontology of urban screens has much in common with film/video art. For instance, many established installation artists have explored modular projections on architectural façades or artifacts in 3D physical space. Iranian-born artist Shirin Neshat's video installations have problematized the *relationship* between different visual events projected in a single pictorial 3D space. In her work, videos that represent entirely different scenes, different viewpoints or asynchronous views of a same scene and/or viewpoint are designed for projection either side by side, or else opposite each other in large exhibition halls.

Manovich uses the term "spatial montage" to describe the relationships between different visual content juxtaposed on a single screen. Spatial montage hinges on how "images appear together, when they appear, and what kind of relationships they enter into with one another" [19]. Since this definition is predicated on a logic of representation, the concept of spatial montage can arguably be extended to multiple screen modularity to describe how distinct content shown on different displays can overlap, intersect, or interact with one another in a single field of view.

Thinking of urban screens in terms of spatial montage is useful in that it offers an ontological basis for thinking about the design of ubiquitous computational media in a modular way rather than in a singular way. It also supports the idea that each module is a node in a network. Finally, it forces designers to be aware of the *relationship between the displays*, rather than seeing them as individual components.

Implications for design

This leads us to suggest that the first medium specific property of urban screens is the modularity of its components and how these relate to one another. Specifically, as regards HCI, the design concern is multiple screen modularity which problematizes the *relationship*s between each display. In this context, principles of spatial montage can help designers think about these relationships. For instance, on a very basic level, designers must take into account how the form, size and content of one display relate to that of other displays, or think about how content from one display can complement, or be transferred to another.

Although it originated in cinema, the concept of spatial montage offers a vast repertoire of tools to deconstruct and reconstruct a space of representation. For instance, comic art storyboarding techniques; split screen effects such as the ones commonly used in the popular TV show "24"; and Orson Welles' use of depth cues in cinema to create spatial zones within a frame, are all different forms of spatial montage that can be remediated to urban screens.

Understanding urban screens in terms of multiple screen modularity and spatial montage can help designers think through the problem of introducing additional spatial dimensions into a medium that already has three dimensions by using *juxtaposition* in 3D physical space. We refer to this as *paradigmatic interaction*. Although Manovich offers an excellent comparison of the *paradigmatic dimension* and the *syntagmatic dimension* in new media theory [19], we found in Gibson a passage that clarifies the distinction between the two in simple terms:

> The gross change of illumination with sunrise and sunset is analogous to the crude difference of intensity at the horizon of earth and sky, although one is a difference of sequential order and the other is a difference of adjacent order [10].

Gibson's "sequential order" is the syntagmatic dimension. It places more emphasis on the temporal. By contrast, the paradigmatic dimension, which finds its expression in the "adjacent order" of spatial montage, has a space bias. With this in mind, we suggest that paradigmatic interaction refers to the non-linear (non-sequential) order of elements in a design space which a user can *simultaneously* interact with.

An example of a design strategy that supports paradigmatic interaction can be seen in GUIs that now heavily rely on a *logic of selection* by simultaneously offering a repertoire of choices (paradigmatic dimension) as compared to the

sequence of actions (syntagmatic dimension) that existed in old command-line interfaces. Spatial montage allows an epistemological shift that favors the paradigmatic over the syntagmatic dimension. Arguably, this can trick people into seeing themselves as present in multiple locations at once.

Propriospecificity, Presence, Performative Interaction

Orson Welles was able to use depth cues to modularize space for the purpose of *mise-en-scène* because our brain can construct the illusion of depth when we watch movies on a big two-dimensional screen or when we experience a virtual reality system that simulates 3D space [6]. We then become immersed in a 3D space that has nothing to do with our immediate physical space: our visual attention is displaced from our physical setting. The literature refers to this as *extended presence* or *partial disembodiment* [41].

Gibson remarked that vision "serves not only awareness of the environment, but also awareness of self" [11]. He drew a distinction between visual stimulation that is exterospecific (how we see an environment we are looking at) and propriospecific (how our vision informs our sense of body awareness within this environment).

In the 1970s, artist Peter Campus conducted experiments exploring the disjuncture between visual perception and proprioception. He did this by showing viewers images of themselves that drew attention to oppositions between the body's movements and their representations. For instance, his installation work "Interface" seen in Figure 2 consists of a large glass panel placed in a dark room displaying a mirror reflection of the observers and a video projection of their image filmed and projected from behind the panel. A hand gesture made on the left can be observed on the left in the reflection (reflected mirror view) but appears on the right in the rear projection (back-projected view). In these experiments, Campus was investigating to what degree a viewer's sense of bodily awareness intervenes in the relationship between vision and embodiment [17].

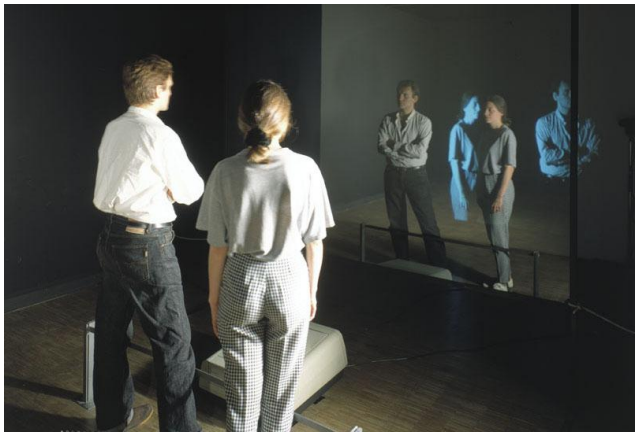

Figure 2- Photo of Peter Campus's 1972 installation work titled "Interface". Interaction with large displays calls for designing with cameras, sensors and motion controllers. ©1972PeterCampus

Forty years later, we have found few studies on this topic in the field of HCI. This is surprising considering the fact that proprioception is the quintessence of embodied interaction; it has been described as the only sense "by which the body is aware of itself" and *whereby one's own body is used both as the subject and object of perception* [24]. Proprioception interprets and updates data acquired on body posture, position and movement to provide a sense of awareness of one's bodily presence within an environment. This leads us to say that embodied interaction, and its correlate, disembodied interaction, are directly related to proprioception, which itself problematizes *presence*, a thorny concept that remains hard to define, test and analyze in scientific research. Indeed, it may be because of its elusive character that there is so little research that investigates embodied vs. disembodied presence in HCI.

With the exception of work being done on vection in the field of virtual reality simulation [33], presence tends to be mostly studied as a disembodied cognitive construct often referred to as immersion (flow and engagement) [27]; as a relational concept related to degrees of participation [2]; or as a spatial variable in the context of proxemics [13]. In HCI, physical presence is typically studied from an engineering perspective where sensors are used to detect and analyze attention, position, orientation and movement.

For instance, CHI 2012 papers on large digital displays focused on physical presence by measuring levels of interactivity with a media façade [7], chained displays [38], interactive shop window displays [26] and tabletops [1]. None of these were explicitly concerned with one's awareness of spatial presence, but all sought to understand space utilization around displays. Of particular interest to our investigation is the fact that two of these four papers discussed interactivity in terms of *performative interaction*: users were interacting with images of themselves on the screen [26, 38], while a third was concerned with users using SMSlingshot to interact with a digital façade [7].

Implications for design

We suggest that this speaks to the fact that in environments with large displays, presence is the elephant in the room. We believe that what attracts users to interact with large screens is first and foremost representations of themselves, of people they know, of things they do, and of their own power to act upon these representations through handheld devices or motion controllers. Indeed, self-perception in large public displays has been identified as a design factor for *attracting attention to*, and *communicating the interactivity of*, this platform [15, 26]. In this sense, proprioception, the physical sense of oneself in an environment (embodiment), or of absence from this environment (disembodiment) can be said to be a key modality in interaction with digital displays. With this in mind, we purport that propriospecificity is the second medium specific property of urban screens with *represented presence* thus being a fundamental design factor.

Exploring *how* representations of the self in relation to the embodied self can provocatively be opposed, presented out of synch, multiplied or manipulated to inhibit or enhance interaction in an environment that includes large screens has been an ongoing area of experimentation in the performing arts. More recently, a performative interaction framework has found some traction with HCI practitioners.

Reeves has proposed a framework to analyze a spectator's experience when watching someone use interactive technology [32]. Sheridan has done a considerable amount of work on performative tangible interaction, with a more flexible framework that looks at how users can transition into various levels of activities: spectating, participating and performing [36]. Her work calls for developing innovative devices that capture, update and generate data on orientation, posture, body movement or fine motion (e.g. fingers or wrists) to explore and produce new forms of playful performative interaction. Like them, we believe that drawing on some of the concepts of performance art would greatly benefit public space technology design since research has shown that digital displays that have artistic content and strategies tend to attract more attention [15].

Manovich argued that in the late 1990s, the design of GUIs was already treating interaction like an aesthetic event which "explicitly calls attention to itself" [21]. This was most evident in the "multimedia drama" of light, glowing colors, animation, sound and sometimes vibration that occurred when a computer or mobile phone was turned on.

Architectural lighting, Phototropism, Photokinesis, Theatrical Interaction

In *Computers as Theatre*, Laurel suggested that interaction with an interface can take the form of a theatrical performance. Noting that some designers compared computer users to theatrical audiences, Laurel asked: "What would it be really like if the audience marched up on the stage?" and the encounter was made more interactive [18].

Mostly active in the fields of digital storytelling, interactive fantasy and game design, Laurel may not have thought of her human-computer-interaction-as-theatre metaphor in the context of urban screens. However, we would argue that environments that contain large digital displays actualize this metaphor better than any other computational platform. The reason for this being that in urban screens, the stage is neither a two-dimensional GUI, nor an immersive virtual reality setting. Instead, it is a three-dimensional real life physical setting in which the audience performs their (inter)actions with technology on the stage of public space.

The shape and atmosphere of this stage is defined by architectural illumination and more importantly, by the immersive luminous colors emitted by the digital displays themselves. Evidently, this can translate into very different impressions depending on atmospheric conditions and time of day. Night-time adds more drama to an outdoor urban screen environment than daytime. However, any installation with luminous screens or accent lighting evokes a certain theatricality, one could even say, a sense of the spectacular. Lighting is an essential part of the technical "magic" that Laurel describes in reference to theatre. Light itself has long been used as a material, albeit in its immaterial form.

Whether they remediate architecture, theatre, photography or cinema, and whether they are static or dynamic, displays *always need light and contrast*. They either emit radiant light (LED or LCD screens) or create ambient light (media façades that reflect projected light) that floods and remaps the architectural environment into different spatial schemes. As the designer of media façades observed, light literally "paints the space" [Amahl Hazelton, interview, 2011].

Implications for design

For this reason, we purport that architectural lighting is an essential attribute of urban screens as a medium, and thus its third medium specific property. In our search of the literature, we found no works that study, let alone mention, the light generated by large digital displays as a factor in HCI research. However, we suggest that it has as much potential in device/technology-focused research as in art.

In their longitudinal study of 46 large digital displays, Huang et al. have made observations "in the wild" on people's awareness of displays and found that "users paid attention only very briefly to the displays if at all" [15]. All their field observations were conducted in well-lit environments in which the ambient light matched or overpowered the intensity of light emitted by the displays. Would their findings have been different if the contrast had been intensified? None of their design recommendations mention lighting, yet Gibson provides us with invaluable theory that strongly suggests light can draw people in:

> The essential feature of ambient light as a potential stimulus for an organism is that intensities are different in different directions. Even in the simplest organisms there seems to be an ability to respond to a difference of intensity in the light falling on one half of its body and that falling on the other. This is the basis of phototropism [10].

Phototropism describes how a living organism responds to light by reorienting itself towards it. *Photokinesis* describes how a living organism moves in response to light. Both phenomena are integral to Gibson's Ecological Approach to visual perception which assumes that people are attracted to light and move in relation to it [10]. If architectural lighting is a medium specific property of urban screens, their power of attraction heavily depends on *how* people are affected by the light emitted by displays or reflected around them.

Architectural lighting designers are trained to consider the effect that light and color have on people. They know, for instance, that light can influence people's feelings or moods in regard to a certain place, and thus, they can exercise a certain degree of control on an environment by using light

as a means to produce specific effects. This can include the use of a seamless, continuous emission on a large expanse with zones of high contrast; or a flickering light that one cannot help but notice; reflective, glossy surfaces; the choice of vibrant hues; or contrasting warm with cold colors. To artists who design environments, those are tricks of the trade, the smoke and mirrors of design through stage lighting or architectural illumination, crafts that have shaped our experience of cities. Richard Kelly, for instance, was a pioneer in using electric light as a new building material to create the effect of "nocturnal modernity", whose "roots could be traced back to the theatre" [28].

However, we suggest that in HCI research, investing time in the study of light and architectural lighting as a design factor in urban screens has much richer implications. Given that lighting and drama are often associated, and as we have seen, are intimately tied in the art of theatre, we propose that the term *theatrical interaction* be used to designate forms of interactivity that affect the dynamic generation of light in urban screens, and by extension, in digital displays. Applied to HCI, this could mean, for instance, that when people approach a digital display, it becomes brighter, more colorful or its cycle of images slows down or speeds up.

Specifically applied to artistic works, this could mean that the lighting emitted by, or reflected off, the digital displays responds to, and interacts with, motion. Such motion can be registered from the actual position changes of passersby, of moving cars, or of changes in other digital displays, and it can ostensibly trigger emergent AI interactivity.

Motion, Agency, Kinesthetic Interaction

Whether digital displays are static or dynamic, we purport that urban screens are *necessarily dynamic as a medium*. Understood as an environment, it is by its very nature a space of motion in at least three regards: first, in how interactants choose to physically navigate their way around them; second, in how other elements circulate and move in the environment (e.g. people, cars); and third, in the way that light dances on digital displays as their images change.

At this point in our discussion, it is necessary to remark that in practice, there is always overlap between different medium specific properties. So far, we have discussed how spatial montage, propriospecificity and lighting can each constitute a distinct basis for interaction in an environment with digital displays. If we take as an example how light could be used to steer observers' attention or movement in a given direction, or else conversely, an observer's presence or movement could affect the light emitted by a display, then in effect, this scenario could involve light/theatrical interaction; presence/performative interaction; and possibly multiple screen modularity/paradigmatic interaction. Although this paper proposes to analyze them as distinct properties, design factors and modes of interaction, each triad is necessarily determinant because a medium specific property is defined as what is *essential* to a medium.

Motion, we argue, is the fourth medium-specific property of urban screens, especially the movement of interactants who forge their own path through the kinetic momentum of the streets and the *mêlée* of people, buildings, displays, traffic and more. To physically move through a space, one must exercise judgment and effort. Choices made at every moment not only determine a trajectory, they also empower people in their experience of their environment. While proprioception implies presence, movement infers *agency*.

Thus, agency is associated with purposive and voluntary motion enacted by the subject. The challenge in the design of urban screens is to provide opportunities for interaction not only with screen interfaces but also with the environment in such a way that one *participates through movement*. Such a form of interaction, we call *kinesthetic interaction*, because it is expressed through movement of the body as a whole within a physical setting rather than the gesture of a finger over the surface of a flat interface.

Fogtmann et al. have already proposed the concept of kinesthetic interaction to describe how "the body in motion experiences the world through interactive technologies" [8]. Although their model treats proprioception and kinetic motion as one (because the former is included in the latter), they do draw a clear distinction between the two:

> The difference between the two is that kinesthesis is kinetic motion, while proprioception is the *sensory faculty of being aware* of the position of the limbs, and the state of internal organs (italic emphasis added) [8].

In the context of urban screens and our ontological framework, we purport that this distinction is prominent because proprioception affects our sense of physical awareness and presence (which is not necessarily related to being in movement and can simply result from one's sense of immersion inside or with a space of representation), whereas kinesthesis focuses on *how we move our body*.

Implications for design

Although it is primarily concerned with the development of devices for smart phones, tablets and vehicles, mobileHCI arose to address the challenge of designing technologies for users moving through different contexts and settings [4]. Kinesthetic interaction arguably shares many of the design issues encountered in mobileHCI. However, this article is concerned with developing high level concepts that speak to the aesthetics and poetics of urban screens, not the development of new services and commercial applications.

With this in mind, we find that kinesthetic interaction is more closely aligned with the proxemics interactions framework, a top-down conceptual model for interaction that adopts an ecological approach to study the spatial relationships between people, devices and non-digital things [13]. This framework has been specifically applied to the development of digital displays that track and identify objects attached with markers designed to take into account

five parameters: *distance*, *orientation*, *identity*, *movement* and *location*. In fact, the proxemics interactions framework operationalizes a form of kinesthetic interaction into discrete, analytical (measurable and applicable) processes. Research in this area is most promising for urban screens.

However, the purpose of the proxemics interaction framework is to infer design interaction techniques that make digital devices "smart" in relation to people and other devices in their surroundings. By contrast, the kinesthetic interaction concept is not device-driven. It more broadly designates all forms of interaction related to an entity moving in space, and places the emphasis not on devices (smart displays), but on the sense of agency, pleasure, power and embodiment experienced by interactants. This difference has important implications for design.

As with mobileHCI and proxemics research, the nuts and bolts of kinesthetic interaction may come from advances in sensor and actuator technologies [8], but it differs from the former two in that its aim is to engage users beyond the regime of the embodied visual. It is noteworthy that this distinction underscores a growing trend in HCI research that combines sensory modalities such as vision, sound and haptics [4]. We see this, for instance, in smart phones vibrating or playing a tune to signify proximity to a given location or device, such as crossmodal displays [30, 35].

Transduction, Synaesthesia, Crossmodal Interaction

There are many ways in which the ecology of urban screens can be understood as crossmodal or synaesthetic, that is, a medium that can produce sense-impressions of one kind which are transformed into, or associated with, sense-impressions of another kind. When Gibson discussed how sense-impressions of different kinds can overlap with one another, that is, how they are not mutually exclusive, he was describing multimodal perception [10]. Coming from a radically different ontological and epistemological stance which rejects the person/environment dichotomy, the phenomenologist Maurice Merleau-Ponty's claimed that people have a "synaesthetic perception" of environments [23]. What he meant by this is that although at any given moment, one sense may dominate over another, different sensory modalities intermingle and mutually resonate as sense impressions *migrate* from one sense to another. For instance, we can see the softness of an object or hear the thump of a falling body even when observed without sound.

The assumption behind paradigms such as ubiquitous computing, computational materiality, tangible interaction and material interactions is that we need cognitive tools and a vocabulary to understand and describe how the digital and the material co-exist to enable HCI practitioners to treat them in a single unified model [43]. This would purportedly allow designers to freely move from one to the other, and users to experience them both simultaneously.

Of course, this distinction between the material and the digital exists only in the context of analysis, that is, they are simply operational concepts. When we use computational media, we do experience it as both "atoms and bits". This permeability between the material and the digital constitutes one of the most essential characteristics of digital media: *transduction*, the ability to capture, alter and output data into different forms and media [41]. What is most peculiar about computational media is that its tangibility exists in parallel with this medium specific property, which is supported by the very substance that digital information is made up of: electrons [19]. It is by virtue of this paradoxical ontological condition that digital media can radically reconfigure our sense of space and time, remediate a medium into others and more importantly, create conditions that can support crossmodal experiences.

Neuroscientists have already long identified a cognitive process whereby a sensory modality is "transduced" into another. This neurological condition which affects a small segment of the population is called synesthesia. For instance, some synaesthetes, hear a specific sound in response to visual motion, while others will see the digit 7 as yellow and 3 as red [6]. Ramachandran describes synaesthesia as a form of crossmodal abstraction, that is, a cross-activation between distinct, but adjacent neurological areas of the brain. One of his hypotheses is that it is this process that enables us to understand and make metaphors and learn and use language [31]. He offers a model for envisioning the cognitive process through which a sensory perception can be transformed into, converge towards, or interact with, two or more other sensory modalities.

Like all digital media, urban screens have the ability to make crossmodal experiences possible by processing impressions of a kind captured as input into impressions of another kind produced as output. Transduction is in fact what digital media does: it causes the physical nature of a form to be converted into another. It is with this mind that we propose that the fifth medium-specific property of urban screens is transduction. What is peculiar about urban screens is that this phenomenon takes place on an architectural scale, thereby offering a wider range of perceptual experiences than static or smaller digital media.

Implications for design

In HCI, crossmodal interaction already exists [30, 35]. It is not to be confused with multimodal interaction. Although there is often overlap between the two, the distinction between them is simple. As with synesthesia, the former implies a single input that yields more than one perception across sensory modalities, while the latter implies more than one input each affected to its own sensory modality (combined or in alternance). In other words, the first is like a single cable that carries data that can be said to be in a perpetual state of flux and instability, while the other is like a bunch of cables each transporting their own stable signal.

Although it is beyond the scope of this article to ambitiously explore all the forms crossmodal interaction

could take, we will simply suggest that designing for crossmodal perception is the most obvious strategy. We have already presented four design strategies to facilitate crossmodal interaction with dynamic digital displays in public space [9]. Practically speaking, this may involve deliberately using materials, colors, forms and design strategies that appeal to several sensory modalities, that stimulate perception across several senses or that indirectly awaken one sense through another as when a sound is heard in response to a visual stimulus. In art, this effect is often achieved by association or through evocative designs.

However, given the fact that digital media technology offers a vast potential to support crossmodal interaction through its capacity to remediate input from one media or form, into output from another, we purport that transduction is the medium specific property that offers the greatest potential in the design of urban screens. In a sense, other medium specific properties of urban screens derive from it.

For instance, several interactive artifacts already deployed in the urban screen environment presented in Figure 1 were designed for crossmodal interaction. This includes media façades that show an animated image of a plant that grows in response to levels of ambient noise; a video of a chewing gum balloon that inflates when people blow into their smartphones; and a giant-size WORDLE™ algorithm that displays recurring words captured onsite by microphones. Other designers have also discussed the possibility of building interactive crossmodal "urban furniture" (e.g. benches, kiosks) within this urban screen environment. Currently, 21 swings each emit a musical note triggered by motion. When all the swings are being used, a unique symphony is created through public interaction. Such ideas no longer belong to the architecture of utopia, but are now the domain of creativity and cognition in urban screens.

CONCLUSION

This paper has proposed an ontological framework that can support different forms of interaction in urban screen environments. Our analysis emerged out of the observations we made of an existing infrastructure of eight permanent digital media façades in the downtown core of Montréal, Canada. From this process, we identified five medium specific properties, that is, attributes that define the peculiar nature of this computational media platform: multiple screen modularity, propriospecificity, architectural lighting, motion and transduction. Each of these attributes has been discussed in relation to sensory modalities and design factors in order to help HCI practitioners reflect on the aesthetic, poetic, cognitive and experiential aspects of environments that include two or more digital displays.

Our claim is that as physically imposing new media platforms, urban screens constitute a new ontological paradigm in which technology, the body, and space, intersect and interact in unique ways. It is not unreasonable to assume that, as they become more and more ubiquitous in public space, digital displays warrant new modes of interaction that can support a wider range of artistic applications and aesthetic experiences. Researchers have already remarked that there is a need to study and theorize the computational poetics and aesthetics of dynamic digital displays in urban space from a fine arts perspective to guide the development and evaluation of new designs [20].

With this theoretical exploration, we have sought to make a first foray in this direction. Researchers, designers and artists now need to customize these ideas and work through them, as we are in the process of doing in preparation for the design and deployment of future urban screen projects.

ACKNOWLEDGMENTS

We thank SSHRC for funding this work. Some of the references cited in this paper are included for illustrative purposes only.

REFERENCES

1. Benford, S., Crabtree, A., Flintham, M., Greenhalgh, C. Koleva, B., Adams, M., Tandavanitj, N., Row Farr, J., Giannachi, G. and Lindt, I. Creating the spectacle: Designing interactional trajectories through spectator interfaces. *ACM Transactions Computer-Human Interaction 18*, 3, Article 11 (August 2011), 28 pages.
2. Brignull, H. and Rogers, Y. Enticing people to interact with large public displays in public spaces. In *Proc. INTERACT'03*, ACM Press (2003), 17-24.
3. Churchill, E.F., Nelson, L. and Denoue, L. Multimedia fliers: Informal information sharing with digital community bulletin boards. In *Proc C&T 2003*, Kluwer Academic Publishers (2003), 97-117.
4. De Sa, M. and Churchill, E.F. Mobile augmented reality: A design perspective. In *Human Factors in Augmented Reality Environments*, W. Huang, L. Alem and M.A. Livingston, (Eds.), Springer : London (2013), 75-100.
5. Dourish, P. *Where the Action Is : The Foundations of Embodied Interaction*. MIT Press, Cambridge, MA, 2001.
6. Enns, J. T. *The Thinking Eye, The Seeing Brain: Explorations in Visual Cognition* (First ed.). W.W. Norton, New York, NY, 2004.
7. Fischer, P.T. and Hornecker, E. Urban HCI: Spatial aspects in the design of shared encounters for media façades. In *Proc. CHI'12*, ACM Press (2012), 307-316.
8. Fogtmann, M. H., Fritsch, J. and Kortbek, K.J. Kinesthetic interaction: Revealing the bodily potential in interaction design. In *Proc. OZCHI '08*, ACM Press (2008), 89-96.
9. Fortin, C., Hennessy, K. Baur, R. and Fortin , P. Beyond the vision paradigm: Design strategies for crossmodal interaction with dynamic digital displays. In *Proc. PerDis'13*, ACM Press, Article 11 (June 2013), 6 pages.

10. Gibson, J.J. *The Senses Considered as Perceptual Systems*. Houghton-Mifflin, Boston, MA, 1966.
11. Gibson, J.J. A theory of direct visual perception. In *Perception*, R. Schwartz (Ed.), Blackwell Publishing Inc., Malden, MA, Oxford, (1972/2004), 158-174.
12. Gibson, J.J. The theory of affordances. In *Perceiving, Acting, and Knowing*, R. Shaw and J. Bransford (Eds.), Lawrence Erlbaum Ass.: Hillsdale, N.J. (1977), 67-82.
13. Greenberg, S., Marquardt, N., Ballendat, T., Diaz-Marino, R. and Wang, M. Proxemic interactions: The new ubicomp? *Interactions 18*, 1 (January 2011), 42-50.
14. Huang, E. M. and Mynatt, E. Semi-public displays for small, co-located groups. In *Proc. CHI'03*, ACM Press (2003), 49-56.
15. Huang, E.M., Koster, A. and Borchers, J. Overcoming assumptions and uncovering practices : When does the public really look at public displays? Unpublished paper submitted to *PERVASIVE'08*, 1-18. http://www.elainehuang.com/huang-koster-borchers-perv2008.pdf
16. Kaptelinin, V. and Nardi, B. Affordances in HCI: Toward a mediated action perspective. In *Proc. CHI'12*, ACM Press (2012), 967-976.
17. Lageira, J. Peter Campus: The body in view. *Parachute: Contemporary Art Magazine 121* (Winter 2006), 16-41.
18. Laurel, B. *Computers as Theatre*. Addison-Wesley Publishers Reading, MA, 1991/1993.
19. Manovich, L. *The Language of New Media*. MIT Press, Cambridge, MA, 2001.
20. Manovich, L. The poetics of augmented space: Learning from Prada, (2005), 1-28. http://www.manovich.net
21. Manovich, L. Interaction as an aesthetic event, (2007), 1-8. http://www.manovich.net
22. Mankoff, J., Dey, A. K., Hsieh, G., Kientz, J., Lederer, S. and Ames, M. Heuristic evaluations of ambient displays. In *Proc. CHI'03*, ACM Press (2003), 169-176.
23. Merleau-Ponty, M. *Phénoménologie de la perception*. Gallimard, Paris, France, 1945.
24. Montero, B. Proprioception as an aesthetic sense. In *The Journal of Aesthetics and Art Criticism 64*, 2 (2006).
25. Mueller, F. F., Edge, D., Vetere, F., Gibbs, M.R., Agamanolis, S., Bongers, B. and Sheridan, J.G. Designing sports: A framework for exertion games. In *Proc. CHI '11*, ACM Press (2011), 2651-2660.
26. Müller, J., Walter, R., Bailly, G., Nischt, M. and Alt, F. Looking glass: a field study on noticing interactivity of a shop window. In *Proc. CHI'12*, ACM Press (2012), 297-306.
27. Nacke, L. and Lindley, C.A. Flow and immersion in first-person shooters: Measuring the player's gameplay experience. In *Proc. Future Play'08*, ACM Press (2008), 81-88.
28. Neumann, D. (Ed.) *The Structure of Light: Richard Kelly and the Illumination of Modern Architecture*. Yale University Press, New Haven, MA, 2010.
29. Norman, D.A. Affordance, conventions, and design. In *Interactions 6*, 3 (May 1999), 38-43.
30. Olivier, P., Cao, H., Gilroy, S., Jackson, D. Cross-modal ambient displays. In *People and Computers XX - Engage, Proc. HCI'06*, Springer, London (2007), 3-16.
31. Ramachandran, V.S. *The Emerging Mind: Reith Lectures 2003*. Profile Books Ltd., London, UK, 2003.
32. Reeves, S., Benford, S., O'Malley, C. and Fraser, M. Designing the spectator experience. In *Proc. of CHI '05*. ACM Press (2005), 741-750.
33. Riecke, B.E. and Schulte-Pelkum, J. Perceptual and cognitive factors for self-motion simulation in virtual environments. In *Human Walking in Virtual Environments*, F. Steinicke, Y. Vissell, J.L. Campos, and A. Lecoyer (Eds.), Springer, Berlin (2013).
34. Rogers, Y. New theoretical approaches for human-computer interaction. *Annual Review of Information, Science and Technology 38*, (2004), 87-143.
35. Rukzio, E., Schmidt, A. and Krüger, A. The rotating compass: a novel interaction technique for mobile navigation. *Ext. Abstracts CHI'05*, ACM Press (2005), 1761-1764.
36. Sheridan, J.G. and Bryan-Kinns, N. Designing for performative tangible interaction. In *International Journal of Arts and Technology 1* (3/4) (2008), 288-308.
37. Struppek, M. Urban screens - The urbane potential of public screens for interaction. *Intelligent Agent 6*, 2 (August 2006).
38. Ten Koppel, M., Bailly, G., Müller, J., and Walter, R. Chained displays: Configurations of public displays can be used to influence actor-, audience-, and passer-by behavior. In *Proc. CHI'12*, ACM Press (2012), 317-326.
39. Turnovský, J. *The Poetics of a Wall Projection*, Kent Kleinman (Trans.), Architectural Ass., London, 2009.
40. Vande Moere, A. and Wouters, N. The role of context in media architecture. In *Proc. PerDis'12*, ACM Press, Article 12 (June 2012), 6 pages.
41. Van Loon, J. *Media Technology : Critical Perspectives*. Open University Press, Maidenhead, UK, 2008.
42. Vogel, D. and Balakrishnan, R. Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users. In *Proc. UIST'04*, ACM Press (2004), 137-146.
43. Wiberg, M., Ishii, H., Dourish, P., Rosner, D., Vallgårda, A., Sundström, P., Kerridge, T. and Rolston, M. "Material interactions": From atoms & bits to entangled practices. *Ext. Abstracts CHI'12*, ACM Press (2012), 1147-1150.