Augmented Urban Experiences

Technologically Enhanced Design Research Methods for Revealing Hidden Qualities of the Built Environment

ABSTRACT

The built environment is a complex juxtaposition of static matter and dynamic flows, tangible objects and human experiences, physical realities and digital spaces. This paper offers an alternative understanding of those dichotomies by applying experimental design research strategies that combine objective quantification and subjective perception of urban contexts. The assumption is that layers of measurable datasets can be afforded with personal feedback to reveal "hidden" characteristics of cities. Drawing on studies from data and cognitive sciences, the proposed method allows us to analyze, quantify and visualize the individual experience of the built environment in relation to different urban qualities.

By operating in between the scientific domain and the design realm, four design research experiments are presented. Leveraging augmenting and sensing technologies, these studies investigate: (1) urban attractors and user attention, employing eye-tracking technologies during walking; (2) urban proxemics and sensory experience, applying proximity sensors and EEG scanners in varying contexts; (3) urban mood and spatial perception, using mobile applications to merge tangible qualities and subjective feelings; and (4) urban vibe and paced dynamics, combining vibration sensing and observational data for studying city beats.

This work demonstrates that, by adopting a multisensory and multidisciplinary approach, it is possible to gain a more human-centered, and perhaps novel understanding of the built environment. A lexicon of experimented urban situations may become a reference for studying different typologies of environments from the user experience, and provide a framework to support creative intuition for the development of more engaging, pleasant, and responsive spaces and places.
INTRODUCTION
The built environment is one of the most fascinating yet enigmatic artifacts of the human being. It fuses the physical characteristics of a space with the immaterial properties associated with that space—what Gilles Deleuze would call “intensive” and “extensive” qualities (Deleuze 1994). We perceive our surrounding world as a complex entity resulting from the juxtaposition of static matter and dynamic flows, tangible objects and human experiences, physical realities and digital environments.

Each urban context possesses certain qualities, and even though shared characteristics do exist, those qualities vary from place to place. To capture what makes built environments unique is a matter of both quantitative knowledge of their tangible aspects and individual perception of their immaterial properties. In the field of architecture and urban design the tendency has always been to emphasize this dichotomy. In fact, scientific methods are mostly employed in relation to the technical, physical and material aspects of the built environment, whereas the individual perceptions, emotions and responses conveyed and provoked by architecture are a matter of design intuition (Pallasmaa 2013).

Peter Zumthor famously stated: “I enter a building, see a room, and—in the fraction of a second—have this feeling about it” (2006, 13). Do urban contexts embed the same evocative power? What is the impact of the built environment in shaping individual and collective experiences? The complexity of today’s urban dynamics calls for alternative methods of understanding the human experience for better informing the design of spaces and places. In particular, this paper argues that novel digital technologies and augmenting tools offer unprecedented opportunities for merging quantitative measurements and qualitative analysis of urban contexts to enrich design research processes.

Cognitive science claims that the built environment changes our brain’s structure by modulating the function of genes, and therefore affects our behavior (Gage, quoted in Farling 2015, 183). Without discussing the details of the psychological and biological aspects of human perception, we attempt to offer an alternative look at the experiential nature of cities through experimental strategies. We argue that, by articulating, mapping and exploiting the specificities of places through a multisensory and multidisciplinary approach, it is possible to measure and elaborate on the subjective experience—eventually revealing “hidden” characteristics of cities.

To validate this assumption a few design research experiments performed by the authors’ lab are presented, exploring the role of augmenting and sensing technologies in mediating the interaction between people and the built environment. By operating in between the scientific domain and the design realm, these studies allow us to merge quantitative and qualitative analysis into a hybrid form of design research that can eventually support creative intuition for the development of more engaging, pleasant and responsive spaces and places.

BACKGROUND RESEARCH
Objective Quantification of Urban Qualities
Over the last few years, research interest has grown on methods and tools to capture key criteria, parameters, and indicators for depicting and quantifying the specificities of cities in order to better explain the functioning mechanisms of urban environments (Bettencourt 2013). The assumption is that, by drawing on insights of urban dynamics, flows, and activities, the use of “big data—a cumulative aggregation of information provided by urban systems and users—can improve city management and enable the development of fine-tuned regulations and the prediction of future needs (Glaeser, Luca, and Naik 2015).

The first hints of this tendency to measure and quantify urban parameters can be traced back to the cybernetic movement of the 1950s and ’60s. The emergence of computer systems opened up new possibilities for urban designers and architects to explore correlations between design plans and actual urban activities. In these cybernetic experiments, “the computer could further enhance connectivity while allowing a highly customizable management of ambience parameters” (Picon 2010, 32). In a way, the cybernetic ideal has been replaced today by the “smart city” concept, employing technology as a strategy to optimize processes and operations, increase the efficiency of systems, and monitor urban dynamics (Picon 2015).

As cities become more automated and embedded with sensors, data is being generated in real time as a by-product of communicating the results of such automation processes (Batty 2016). This understanding of the use of technology in urban contexts is supported by urban theories that employ complex numerical models to describe networks of systems and flows—the “science of cities” (Batty 2013). By applying the principle of “scaling,” consistent correlations emerge between morphological characteristics of cities—their size—and socioeconomic markers—such as creativity and wages (Bettencourt 2007).

Technological innovations in data science have also enabled the automatic collection and visualization of multiple datasets on urban dynamics at various levels of aggregation (Andrienko et al. 2013; Sun, Wu and Liu 2013). These tools can then be used to make comparisons and extrapolate information about collective urban activities that address, for instance, the vitality (De Nadai 2016), rhythm (Miranda 2017), or safety (Naik 2014; Salesses...
Subjective Experience of the Built Environment

At the other side of the spectrum of this objective, data-driven approach is the fact that living in cities is undeniably an experiential act. As human beings, we are hard-wired for sensations and emotional states, and these result from the interaction with other people as much as by our own experience with the built environment (Ingold 2011). In that regard, architecture and urban design play a crucial role for the experiential and ambience qualities that places embed. By extending our bodily self through our senses and technological extensions, we are able to grasp qualitative atmospheric entities of complex environmental situations (Pallasmaa 2014).

An earlier attempt to better understand this experiential character of cities emerged in the Psychogeography movement of the 1960s. Articulated by Guy Debord as “the study of the precise laws and specific effects of the geographical environment, consciously organized or not, on the emotions and behavior of individuals,” the research pursued by the related Situationist International was indeed looking at the spatial arrangement of the elements of the urban setting in close relation with the sensations they provoke (Sadler 1998).

Acting as a modern version of the urban flâneur, William H. Whyte showed that through the power of simple observation, recording and interviews, one can derive meaningful conclusions on the impact of the built environment in the behaviour of people (Elsheshtawy 2015). Jane Jacobs further explored this sensorial character of cities arguing that not just sight, but instead all the human senses should be taken into account when observing how people interact with places (Jacobs 1961). All these studies eventually translated into planning recommendations and urban policies with the work of Jan Gehl (2006; 2010; 2013).

Cognitive science and psychology can support design with a more scientific understanding of the the human experience (Barker 1963; Gallagher 1993). Through recent technological developments, for instance on neuroimaging, “we can now begin to study human responses to various materials (steel, glass, concrete, wood), the dynamics of personal and peripersonal space, our biological responses to certain spatial settings, human responses to particular forms, colors, proportions, textures, light, and vegetation—in short the many enactive variables that compose the built environment” (Mallgrave 2015).

The emerging “neuroscience of the experience of architecture” addresses the very question of the emotional impact of the built environment in the experience of spaces (Arbib 2015, 75). Because we respond to environmental fields of stimuli through multiple senses neurologically interconnected, these studies prove that emotions are deeply embedded in every urban experience with a dynamic relationship between the individuals and the city (Mallgrave 2013). Such new levels of understanding support the evocative power of the built environment with potentially profound implications in architecture and urban design.

METHOD

This study introduces an applied research method to analyze, quantify and visualize the individual experience of the built environment in relation to different urban qualities. The assumption is that the combination of objective and subjective datasets can help reveal a more comprehensive understanding of spaces and places within the city, opening up for novel research and design opportunities that leverage “urbanized” technologies (Sassen 2011). Rather than a top-down collection and aggregation of large amounts of information, the attention of this paper is mainly on intangible urban qualities that can be captured at the individual level.

A few experimental projects share some characteristics with the presented work on the investigation of the emotional aspects of cities (Hauthal 2016; Nold 2009; Quercia et al. 2014). Several studies also attempt to quantify the states of mind of test subjects during, for instance, walking or biking in urban streets through interviews, surveys, or mobile information (Christiansen 2016; Evans 2011; Lin 2010; Ma 2015; Schreuder 2016). Recently, wearable sensing tools such as EEG scanners have been employed as well in public places (Cernea 2011; Collins et al. 2014; Mavros 2012). Experimental art projects then offer interesting cases of sensory experiences through technological augmentation (Schwartzman 2011).

This paper discusses four hybrid experiments within the design research framework’s larger scope of measuring and quantifying both objective and subjective qualities of the built environment, visualizing them and extrapolating meaning, and creating correlations between those qualities and design strategies. This methodology includes the process of “hacking” some of the employed off-the-shelf instruments, that is tools typically used for their designed purposes are specifically customized for the research purposes.

As prototypical case studies, each of the four experiments focuses on specific qualities of the built environment and subjective responses, and creatively employ sensing and augmenting tools:
• **Urban attractors and user attention**, combining surveying and mapping tasks with eye-tracking technologies in walking tests.

• **Urban proxemics and sensory experience**, using proximity sensors and EEG wearable devices to capture the spatial experience through different modes of transportation.

• **Urban mood and spatial perception**, employing mobile applications to measure tangible qualities of built environments and the related subjective feelings.

• **Urban vibe and paced dynamics**, combining vibration sensing and observational data in subway stations as a proxy for studying city beats.

**RESULTS AND DISCUSSION**

**Urban Attractors and User Attention**

In 1960 Kevin Lynch published *The Image of the City*, arguing that people understand their surrounding environment in consistent ways. There are specific elements in the urban space (paths, edges, districts, nodes, and landmarks) that have the most significant impact on people’s mental maps of a place and that make the city “imageable” (Lynch 1960). It remains unexplored, however, whether these findings have any implications in terms of human visual perception of the built environment. Are there any urban elements that are inherently more attractive to the eye than others?

This experiment explores the use of sensor data from a wearable eye-tracker to analyze human attention patterns when navigating built environments. The eye-tracker is employed for non-obtrusive recording of gaze data during a walk, allowing for the measurement of visual perception patterns in response to urban elements. Through mapping the eye gaze of test subjects as they walk along a familiar route, this study aims to add a measured and complementary layer to Lynch’s arguments.

The experiment correlates gaze duration/intensity and different qualities of the viewed objects (color, movement, distance, geometry, etc.). By juxtaposing the eye-tracking results with a map-drawing task, the visibility and the memorability of different elements are also compared. The employed eye-tracking device is a Pupil Dev, a product that comes with a world camera and an eye camera (Figure 2). The video images taken from the two cameras are processed by its proprietary software that translates the position of the pupil from the eye image to the corresponding gaze position as related to the world image (Figure 3). Although the tool is typically used to track eye movement in a controlled setting, this study takes the device out of the lab and into the real world.

The experiment consisted of two main elements, the eye-tracking test and the map drawing task. While walking down the selected street in Cambridge, MA, the 15 test subjects wore the eye-tracker, and at the end were asked to draw a map of the street. The participants were aware of how the eye-tracker functions, and advised to act naturally. However, they were not aware of the map drawing task beforehand, thus distinguishing between the long-term memory of the space and the short-term memory from the immediate experience.

The test results offer an alternative understanding of the relationship between the characteristics of the built environment and the visual attention patterns of users. Through a comparative study of the eye gaze data during the street walk and post-walk mapping exercise, several layers of inconsistency emerge: (1)
the difference between what exists in the built environment and what is seen; (2) the portion of existing information that is taken in through the eye (Figured 4); and (3) what is remembered or processed into memory.

As an ongoing experiment in the application of eye-tracking techniques in urban studies, the results are preliminary and could be improved in accuracy if provided with more advanced technologies and a more rigorous scientific analysis. However, findings so far already suggest the effectiveness of this combined research methodology (wearable sensor along with interview/survey) in exploration of human spatial perception. In fact, this study reveals the subconscious layer of information hidden from commonly used spatial representations—a deeper reading into the effects of design, circumstance, or chance on human cognitive mapping.

**Urban Proxemics and Sensory Experience**

Experiencing the city is most heightened during transit, where different layers of spatial experience are activated and different dimensions of the built environment are exposed. The objective of this experiment is to better understand the varying experiences of each of the primary modes of transportation in the city of Boston. This research draws on the aforementioned Psychogeography studies as well as research on proxemics that sets a particular hierarchy of physical proximity: from the intimate space closer to the body, through the personal and social space, to the public space (Hall 1966).

The experiment investigates the mind’s response to the individual presence within varying typologies of urban environments, intersecting the proxemics zones with different dimensions of mobility. This dynamic experience of the city is also affected by the flow of others in relation to the spatiality of the environment. In the study, a test subject followed a specific route in downtown Boston travelling through three unique neighborhoods, each time using a different mode of transit—cycling, driving, riding the subway, and walking (Figure 5).

Proxemics was studied through a set of proximity sensors directed at the four corners to create a circumscribing illustration of the intrusions into the personal space. In order to investigate the relationship to the mind, an Emotiv EPOC EEG brain scanner was used to track brain activity throughout the experiment and against proximity (Figure 6). The results of the EEG scanner readings were categorized as meditation, excitement, frustration, and engagement. This data was then studied in alignment with the readings from the proximity sensors in relation to first-person footage collected from the experiment (Figure 1).

The analysis of the readings and spatial scenarios are reinterpreted through a lexicon of urban compositions and their deduced impact on the mind. This taxonomy juxtaposes the spatial condition, proximity, and state of mind to generate 99 cases observed in the study (Figure 7). Some cases introduce the impact of people which are by proxy a result of the setting, while others are purely based on proportion and surroundings. These findings at once suggest an enhanced knowledge of the urban fabric and a critical perspective of transit modes.

The accuracy and consistency of the experiment results can certainly be improved, but the large scope of the study allows us to shed light on experiential patterns. In particular, each state of mind is most commonly induced by a specific spatial situation. Highest levels of meditation are achieved in calm and quiet areas but with a certain static object to help orientation and create a sense of scale. Engagement is most commonly associated with people, thus forcing the subject to be alert and engaged in whichever transit activity is being undertaken. Excitement relates, most often, to unexpected or agitated spatial circumstances, including heavy flow of people in the immediate surrounding of the subject. Finally, frustration is most common when people or objects traveling at different velocities are nearby. The outcomes then suggest an inherent relation to flow, whereby the temporal transformation of space is created by people and impacts the state of mind instantly.
Urban Mood and Spatial Perception

The way in which we receive information and data about our interaction and relation to the built environment is largely fed to us through systematized, sensor-based statistics. The common static methods of data collection leave little room for interpretation, and fail to consider the complexities and variables that may influence the ways in which people perceive their surroundings. In fact, each individual experience, perception, and view of places is colored by a personal, subjective interpretation.

This study addresses such additional layers describing the subjective views and attitudes that could potentially have an impact on and influence how urban data is collected, interpreted, and used. In this experiment, “objective” data is quantified by measuring parameters that can offer an overall representation of the analyzed place. In particular, measurements of temperature, humidity, spatial qualities, brightness, and sound levels are performed via smartphone apps that employ embedded sensors or add-ons. These parameters and their combination result in a quantitative description of tangible features of the environment.

The more complex “subjective” experience is instead quantified through two modes of data collection—passive and active. Passive measurement involves processing existing information that is already being transmitted and collected from personal digital devices. These means of data collection are commonly utilized by social media, search engines, and apps for extrapolating information about the users and learning more of their interests, desires, patterns, and habits. Active measurement is achieved through a mobile application specifically designed and prototyped by the research team to get a deeper layer of subjective inputs.

The app is based on the premise of engaging individual users to input basic descriptions of sensorial perceptions through valuation of the varying intensity at which they experience stimuli. The interface is designed to negotiate through a gradient of two extremes, allowing for the translation of intuitive experiences into measured information (Figure 8). When users enter a predominant mood or feeling, a correlation between the experienced phenomena and the emotional response is also created by the app, therefore facilitating the personalization of an individual cognitive landscape (Figure 9).

To test the validity of the research method and tools, a few experiments were performed in different places within Cambridge (Figure 10). The implementation of the app’s subjective data in conjunction with the more passive, objective dataset extracted from complementary sensors, resulted in a series of urban conditions. This alternative understanding of everyday spatial perception allows for novel opportunities and potentials to enhance the interactions between the user and the city through the recommendation and curation of experiences that are personally catered to the individual. By revealing the “mood” of urban environments, this real-time data could also be used by city planners to better inform urban strategies and interventions.
Urban Vibe and Paced Dynamics

Cities have a beat, a pulse created by the speed, forces, and intensity of flows and circulations. Our daily experience is in fact a sequential series of rhythmic routines, in which commuting to work plays a crucial role. In this sense, subway stations provide a unique indicator, a microcosm where to explore these dynamics—the city “vibe.” Travellers and commuters fleetingly inhabit these transitional spaces in environments of variable density, mood, noise level, and pace at all times of the day. However, engrossed in their own trip and isolated by media, subway users do share a space, but not a common experience.

This study explores the use of vibration sensing and observational data collection in subway stations to develop a new understanding of the sensory experience of Boston’s T users. Through documenting the composite “vibe” or “beat” of three sequential stops, the experiment develops a mode of comparison between the experiential qualities of stations and the related sensed data to riders’ behavior and interactions. In the study, the stations are divided into sensory zones, and both rider behavior and vibration data are tracked in each zone (Figure 11). These nested areas include the platform, parts of the station where the user can see the train, and parts of the station where the user can only hear the train. The investigation also spans across four time periods, and data was collected during each of these time-frames at the sensory zones in all the three stations, developing a matrix of variables that shape the vibe of the T.

The “objective” data collection initially relied on a geophone, a seismic sensor that converts ground movement into voltage via an oscillating magnet (Figures 12). In order to measure usable data in a short period of time, the team eventually employed the built-in accelerometer in smartphones via the iVibrometer app (Figure 13). The results show dramatically different vibration profiles for the three stations. For instance, train arrivals and departures cause the greatest vibration when measuring at the platform, but as one moves further from the platform, vibration levels decrease very differently depending on the morphology of each station (Figure 14).

On the “subjective” side, the study results in a new understanding of the way users experience and inhabit subway stations. For instance it was discovered that, contrary to expectations, during rush hour stations remain almost entirely deserted between trains, as crowds disperse quickly to their destinations. The team also identified and documented a series of idiosyncratic user activities that usually remain unnoticed through sectional drawings of the stations.

In trying to draw conclusions from this data, one might be
tempted to correlate user activity to the vibration profile of a particular station. However, to do so would discount the impact of other senses—sight, hearing, smell—on the subway experience, and would overgeneralize the behavior of T riders. Nevertheless, this juxtaposition of subjective and objective observations in subway stations, and the pursuit of a composite result, might serve as a reference study for future experimentations in the understanding of the beat of the city.

CONCLUSION
This paper presented a multidisciplinary approach that creatively combines "scientific purposes" with "design strategies" for a better understanding of the embodiment of immaterial elements of the built environment with the subjective experience of cities. The contaminations between different fields and approaches, these "détournements or unorthodox misappropriations" (Picon and Ponte 2002, 16) are leveraged to create an alternative design research method and open up potential implications in architecture and urban design.

The availability of new technologies—from data analytics to artificial intelligence, from contextual sensing systems to digital augmentation—offers unexplored ways of looking at our surroundings. The paper critically looked at these emerging methods of measuring and inferring, emphasizing the fact that, taken alone, they will not spontaneously generate new knowledge. As our ability to quantify the built environment increases, so does the risk of developing and acting on limited datasets and making conclusions and design decisions that ignore crucial variables that could not fit into available quantitative models.

This work demonstrated that, by building upon objective layers of data and affording them the complexity and variation of subjective, personal feedback, it is possible to gain a more holistic, and perhaps novel understanding of the built environment and of our presence within it. A lexicon of experimented situations becomes a potential framework for studying the different typologies of urban spaces through the creative use of sensing and augmenting technologies.

Future developments of this work will expand the repertoire of "hidden" urban qualities through more refined experimental investigations, and will ultimately translate the resulting body of knowledge into recommendations for architects, urban planners, and city managers for potential integration into their design and decision-making processes. By setting up metrics that are not so commonly considered in design practices, the findings of the presented and future experiments aim to offer alternative insights on how the spatial morphology, the dynamic activities, and the subtle varying conditions of places affect people's perception and behavior, eventually fostering enhanced design methods in which the human experience—and even emotions—are placed at the forefront of design decisions.

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**IMAGE CREDITS**

All drawings and images by the authors and the research team of the Responsive Environments and Artifacts Lab at Harvard GSD.

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