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Public Visualization Displays of Citizen Data: Design, Impact and Implications

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Abstract

In this paper we propose citizen-driven, public data visualization as a tool to support social and civic purposes in public spaces. We argue for the potential of this approach, motivating it with recent trends and developments in the areas of information visualization, urban computing, and urban screens, and we layout a transdisciplinary research approach and methodology. Through three studies approaching our research goal from design, empirical, and reflective perspectives, we show how visualization interfaces, situated in public spaces can improve perception, and lead to sustained behavior change; can increase social awareness and discourse; and can influence meaningful participation and a range of social interactions related to locally relevant topics. We conclude by discussing implications for the design, use and evaluation of citizen-driven public visualization as a tool increase public awareness, participation and discourse.

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

The constant development of ubiquitous computing has enabled the expanded integration of computational, sensing and display technologies into everyday public settings and lifestyles beyond the workplace, including the spaces where we meet, study, play and relax (Greenfield and Shepard, 2007). The ability to measure, monitor and track the digital traces people leave as they go about their daily lives has turned into true capital for an increasing number of urban stakeholders. While global technology companies are offering 'smart-city-in-a-box' solutions, bottom-up structures and individuals advocate active engagement with urban data through DIY urbanism and citizen hactivism. Yet, it is still unclear how this urban data, and the technologies able to acquire and display it, can be of true value to its the citizens who generate it (Townsend, 2010). The combination of data visualization as a means to represent citizen-driven data in attractive and insightful ways, with ubiquitous technologies for displaying, sensing and interacting, could potentially make us more informed and engaged citizens (Foth et al. (Eds.), 2011).

This paper describes a design and empirical inquiry into the potential of citizen-driven, public data visualization for social and civic purposes. Building on trends and developments in the fields of information visualization, urban computing, and urban screens and media architecture, we explore how data visualization, display technology and different data-sensing mechanisms can be combined to promote awareness, discussion and participation. Our research is based on an interdisciplinary approach combining methods from design and computer science, with qualitative methods drawn from ethnography. Inspired by two preliminary design studies into public data visualization, we present the design and in-the-wild evaluation of three data-driven visualization installations. These three visualizations approach the overarching objective from the perspectives of 1) inciting and sustaining behavior change, 2) supporting reflection and discussion, and 3) influencing participation and social interaction. In-the-wild deployments in several distinct public settings have provided insights into how people engage with visualization of data originating from themselves, and how data representation and feedback modalities, the interface and interaction design, and the physical and contextual settings influence this engagement. We conclude by discussing the challenges for the design, use and evaluation of public visualization of citizen-data as a tool to increase public awareness and discourse on socially relevant topics.

2. Background and Motivation

The scope of this research is defined by the overlap between information visualization, urban computing, and urban screens and media architecture (Figure 1). While drawing from and contributing to these three areas, each of them assumes distinct roles in our research:

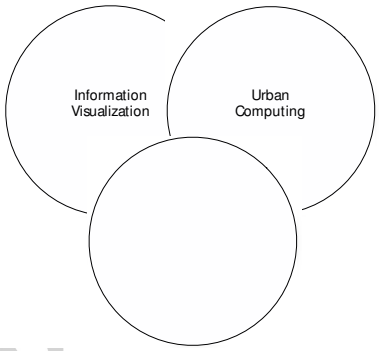

Figure 1: The scope of this research is defined by the overlap between information visualization, urban computing, and urban screens and media architecture.

- *Information Visualization* is our main *source* for research and design. We are motivated by the potential of recent developments in the field, which highlight ambient, social and artistic purposes of visualization. We are interested in exploring visualization techniques adapted to

personally meaningful data sources, and to the social groups and places people live and play in.

- *Urban Computing* provides the conceptual and technological *backdrop* of this research. Rather than focusing on the potentials of ubicomp technologies to improve efficiency and productivity through computational prediction, monitoring and optimization, we adopt a proactive human perspective, which considers ubicomp technologies that can support curiosity, creativity, insight and meaningful action.

- *Urban Screens and Media Architecture* constitute the *medium*, whose particular characteristics and potentials motivate and drive this research.

In the following, we motivate our work by detailing how it builds upon relevant trends and developments in these research areas.

2.1. Information Visualization

Research on information visualization is concerned with the creation and study of interactive and graphical representations intended to make sense of data (Dörk et al., 2009). The most common definition of information visualization, that has been agreed upon is *"the use of computers to interactively amplify cognition, using visual representations"* (Card et al., 1999).

The strength of information visualization lies in supporting the advanced characteristics of the human visual system, in particular its ability for pattern recognition, discerning trends and relationships, and identifying outliers (Ware, 2010). Accordingly, visual representations of information can aid memory, make abstract concepts visible, support problem solving and decision-making, and make the analysis of large datasets more efficient (Myatt and Johnson, 2011). With the arrival of computers, computer graphics and the Internet, information visualization has developed drastically. Advanced technological tools enable faster statistical analyses and data mining, allow the visualization of complex and multivariate datasets, and support interactivity for exploration and in-depth analysis.

Since the establishment of 'infoviz' as a dedicated research community, information visualization researchers have created and studied a wide range of visualization techniques aimed to support the analysis of complex datasets (e.g. Inselberg and Dimsdale, 1991; Johnson and Schneidermann, 1991; Herman et al., 2000). For most of these advances in information visualization, the target audience has been a population of expert users, who possess the knowledge and experience in analyzing problems in specific domains, such as finance, market research, journalism and science. The major purpose of information visualization tools has been to help professional users explore data, generate, refine and test hypotheses, and ultimately to produce insight in goal-oriented, work situations (Pousman et al., 2007).

In contrast, more recent developments highlight ambient, artistic and social purposes of information visualization beyond professional domains, audiences, and environments. In the following, we will introduce these perspectives and illustrate the characteristics that inform our work.

2.1.1. Ambient Visualization

Ambient visualizations (Pousman and Stasko, 2006) are information systems that provide abstract depictions of invisible dynamic processes, such as changes in weather, stock, currency or the amount of human presence or activity in a building, and are located in peripheral locations of everyday physical settings (Rogers et al., 2010). For instance, the Ambient Orb[b] maps stock (or weather) data into the color of a glowing orb, fading slowly from green when stocks are rising to red when stocks are dropping. Ambient visualization aims at providing visually appealing, unobtrusive, and physical interfaces to invisible data streams.

The idea of raising the awareness of people by placing dynamic representations of data in the immediate and public physical surroundings is one of the major concepts that inform the design studies conducted within our research. Furthermore, the concepts of ambience, aesthetics, and seamless environmental integration are specifically explored in our initial Studies 1 – 3 (see *3.3 Overview of Studies*).

2.1.2. Social Visualization

Social visualization focuses on enriching electronic social communication by making its rich and salient qualities visible in easily accessible and understandable ways (Donath et al., 1999). Recent initiatives in this direction have shifted towards democratizing the power of visualization and making its features accessible and usable for the public at large. For instance, *Many Eyes* is an online community platform that allows Web users to upload their data sets, choose visualizations and discuss them with other community members (Viégas, 2007). In this way, social visualization offers non-experts the chance to increase their understanding of complex information by the power of collective and collaborative efforts (Viégas, 2007). Research efforts have also demonstrated how people can be encouraged to create public visualizations for communicative and participative purposes, which by themselves can even provoke sufficient motivation for spurring significant social activities (Danis et al., 2008; Heer et al., 2008; Gilbert and Karahalios, 2009).

These developments around the collective and collaborative exploration of personally meaningful data, combined with the idea of placing visualization in physical everyday settings, introduced with ambient visualization, point to a new perspective on *public social visualization* that informs our design and research approach. Based on evidence from an initial design inquiry presented in our first design

[b] http://www.ambientdevices.com/

study (*AmbientNEWS*), the concept of public social visualization is extensively examined in Studies 4 (*Reveal-it!*) and 5 (*MyPosition*) presented in this paper.

2.1.3. Artistic Visualization

The trend of expanding visualization purpose beyond expert analysis manifest itself also into the increasing use of visualization as a medium for artistic expression (Viégas and Wattenberg, 2007), i.e. applying infoviz techniques to data-driven artworks. *Artifacts of the Presence Era* (Viégas, 2004), for instance, creates evocative views of the flow of human traffic in an art gallery, by recording video and stacking and wrapping it into a visualization according to the sound level inside the space. It constitutes one example among many artistic visualizations (e.g. *Visitor.Files* (Ray, 2005), *Tableau Machine* (Romero and Mateas, 2005), or *Annual Report* (Feltron, 2012), to name a few) that challenge the preconceived notions or ideas of the onlooker about her live, world or environment, by provoking curiosity, puzzlement and reflection (Pousman et al., 2007).

In a more broader sense, our research is influenced by a range of artistically motivated, activist or participatory project and interventions related to data and public space, such as (HeHe, 2005), (Bodle, 2009), or (Breinbjerg et al., 2010). While not systematically studied in scientific terms, these and other projects inspire our work by their approach of augmenting public spaces with abstract, metaphorical representations of data, thus seeking to raise awareness and provoke debate and participation on socially relevant issues.

2.2. Urban Computing

Early research in ubiquitous computing has put considerable effort in investigating how information technology could be diffused into everyday objects and settings and how this could lead to new ways of supporting and enhancing people's lives beyond the desktop (Streitz and Nixon, 2005). Following up on Weiser's idea of *"calm computing"*, those endeavors built on the assumption that the environment, the home, and our possessions would be aware, adapt and respond automatically to our varying comfort needs, individual moods and information requirements. At the same time, the computational and feedback process involved would be calm, unobtrusive and even invisible (Weiser and Brown, 1997). *Proactive computing* was put forward as an approach to determine how to program computers to take the initiative to act on people's behalf, resulting in the domination of context awareness, ambient intelligence, and monitoring and tracking on the research agenda in the field.

Nowadays, advances of digital technology and computation seem to be making the ultimate vision of ubiquitous computing finally possible: the 'computer' as we know it, is becoming embedded in the physical objects and surfaces of everyday life (Mitchel, 2003; Greenfield and Shepard, 2007). Similarly, no longer confined to our offices, schools and homes, the integration of computing, sensing, and actuation technologies is expanding at astonishing rates into everyday urban settings and lifestyles

(Kindberg et al., 2007). Driven by the increasing availability of data, together with the rising affordability of sensors and the now ubiquitous use of mobile communication devices, *urban computing* aims to instrument the human experience of public space with digital information. Since the establishment of this research field, most urban computing systems have focused on improving efficiency and productivity in the city. By connecting unobtrusive and ubiquitous sensing technologies, advanced data management and analytics models, and visualization methods, urban computing research has proposed 'smart' solutions to improve the urban environment, human life quality, and city operation systems, such as inferring air quality (Zheng et al., 2014), automatically detecting anomalous events in a city (Barker et al., 2011), or finding smart driving directions for citizens (Yuan et al., 2010).

Proactive Human Perspective on Ubicomp

However, research has also argued that the existing technological and research endeavors still do not match up Weiser's vision on a world of ubiquitous computing, in spite of their undoubted advances (Rogers, 2006). There is still an enormous gap between the dream of comfortable, informed and effortless living and the accomplishments of ubicomp research, as *"we simply don't do 'smart' very well yet"* (Greenfield, 2010). For instance, context-aware systems that attempt to guide a person through certain activities require models of human behavior and intentionality that are based on rationality and predictability (Salvador and Anderson, 2003). However, people often behave in unpredictable and subtle ways in their everyday contexts. Research around tracking and monitoring of humans has been sensitive to the privacy and ethical problems surrounding the topic, yet little knowledge and insight into other human aspects has been offered. For instance, the potential of recording, tracking and re-presenting movements and other information to facilitate social and cognitive processes has been relatively unexplored (Rogers, 2006). There is also an increasing understanding that public life constitutes a much wider range of emotions and experiences, and that successful urban computing needs to incorporate these perspectives (Paulos and Beckmann, 2006; Townsend, 2010).

These conceptual considerations have been framed into an alternative research agenda, that proposes to recast ubicomp research in the context of the original motivation for designing computers, i.e. as *"tools, devices and systems that can extend and engage people in their activities and pursuits"* (Rogers, 2006). Instead of instrumenting and augmenting the environment with computational technology to reduce the need for humans to think for themselves, *engaging ubicomp* considers how technologies can be designed to augment the human intellect as to support curiosity, creativity, and meaningful action. Technologies can be shaped as ecologies of resources (sensors, mobile devices and shared displays), that can be mobile and/or fixed, to serve specific purposes and be situated in particular places, enabling people to do *"what they want, need or never even considered before by acting in and upon the environment"* (Rogers, 2006).

This conceptual understanding of ubicomp points to a perspective on the acquisition and visualization of urban data that informs the research approach presented in this research. We create ubicomp systems that acquire and present citizen data in engaging and insightful ways, and integrate it in relevant physical

settings. We utilize the public urban space as the context for collecting citizen data, implementing fully functional prototypes of public visualization installations, and studying the impact of public visualization (see Studies 1-5).

2.3. Urban Screens and Media Architecture

Today's *'urban displays'* are publicly accessible interfaces that allow passers-by to observe and potentially interact with functional information, ranging from bus-schedules to tourist information and ticketing (Fatah, 2005). With the growing prevalence and dropping cost of display technologies, urban screens are becoming increasingly ubiquitous, showing up in various public spaces such as museums, airports, bus-stops, squares and parks. In terms of form and material, urban screens have initially included information terminals, LED and plasma screens and signs (Struppek, 2008). However, recently engineering enhancements have led to an expanded notion of the *urban screen* idea through the appearance of large-scale projection surfaces, as well as intelligent architectural surfaces and facades. Nowadays, the nature of such displays can technically reach beyond the traditional flat, rectangular LED display and its derivatives and become integrated within the actual architectural or urban design. Examples for such new display forms may range from subtle digital augmentations of the existing environment (Gaver, 2002) to impressive state-of-the-art material developments for large-scale architectural surfaces, such as (Van der Maas et al., 2009). Consecutively, architectural surfaces can be transformed into dynamic moving images forming new architectural material and structures. Conversely, dynamic digital information, originally displayed on dedicated multimedia screens (desktops, smart phones, or tablets), obtains the potential to become a construction material within the urban environment shared by everyone.

Content-wise, the obtrusive presence of its typically large, light-emitting panels is turning *media architecture* in an expressive language of its own right, influencing people's experience of public space (Goffman, 1963; Venturi et al., 1977). However, the majority of currently existing media architecture installations still predominantly deploy commercially motivated digital imagery, such as advertisement of consumer goods, or broadcasting of mass sports and music events. In this context, several media, urban and social theorists have questioned the status quo of the urban mediascape as *"a subject of privatization, rationalization and functionalism"* (McQuire, 2007; Huhtamo, 2009). Subsequently, there has been an increase in studies of new concepts, methodologies and experiments uncovering the potential of media architecture as mediator for the social encounter between citizens (Struppek, 2008), the construction of reflection and collective memory (Broeckmann, 2009), or the influence on consciousness and behavior (Bounegru, 2009). Yet, academic research in the field of urban computing has been mainly driven by technical challenges, such as the development of fast responding lighting systems or kinetically moving structures. While urban interaction design have outlined the challenges and opportunities of urban screens and media architecture (Dalsgaard and Halskov, 2010), its social impact is still largely unexplored, with only few studies presenting a civic goal (rather than a playful goal or none at all) (Ananny and Strohecker, 2009; Leong and Brynskov, 2009; Schroeter, 2012).

Urban screens and media architecture assume a pivotal role in our research. We align with the increasing understanding that urban screens and media architecture can grow beyond the broadcasting of artistic visual imagery, public announcements, or persuasive slogans, and focus on social and civic values. Exploring their particular characteristics such as the explicit public dimension, visual presence and opportunistic accessibility, we propose the use of urban screens as medium for the visualization of contextually relevant citizen data in public space, and study the impact of visualization displays on stimulating and influencing awareness, reflection and participation.

3. Research Approach

It is our overarching objective to understand the potential and impact of visualization in public space. In particular, we aim to investigate how public data visualization, combined with sensing and display technologies can be conceived to incite and support awareness, discussion and participation. We are interested in how interfaces can be utilized to help sense or acquire citizen data within everyday settings and how visualization techniques and methods can be adapted to personally meaningful data sources and to the social groups people play and live in. In particular, we focus on public settings characterized by dynamic, casual and opportunistic use patterns, and diverse and less-analytically minded audience. Rather than merely informing people about specific functional information, public visualization displays may provide ways to motivate new insights and behaviors by stimulating engagement and augmenting awareness of people within an appropriate physical context, and by supporting personal reflection and individual and collective exploration.

3.1. Research Questions

The fundamental hypothesis of our research is that the visualization of contextualized citizen data can increase awareness, and promote participation and discourse in public physical settings. To approach this hypothesis, we pose the following research questions:

- Q1. How can we design public visualization of citizen data for awareness, discussion and participation?
- Q2. What is the impact of public visualization, when deployed in real-world public settings?
- Q3. What are the implications for public visualization as a tool for influencing the opinions, attitudes and behaviors of citizens?

These questions guide our overall research. We formulate them in an open-ended manner that corresponds to a research process drawing from several related disciplines and incorporating multiple methods. While these questions are defined broadly, we look for answers in the context of specific domains and scenarios. Focusing on open-ended, casual and social public settings, we seek to envision visualization interfaces of data, that originate from people's everyday dealings and activities, and can support awareness, reflection and social, community-driven communication on locally relevant issues.

3.2. Research Methodology

The open-ended nature of the challenges this research addresses calls for methodologies that allow for practical, empirical and reflective exploration of the underlying research goals. We adopt a threefold methodology. Each of the following research activities - design studies, in-the-wild evaluation, and critical reflection - approaches one of the three main research questions (Q1-Q3).

3.2.1. Design Studies

To explore the possibilities of data visualization combined with situated display and sensing technologies for influencing awareness, discussion and participation (Q1), we follow a *"research-through-design"* approach (Zimmerman et al, 2007). We present five design case studies that integrate visualization, interface and system design with a prototype implementation and deployment. While each of these studies is examined with a specific scenario, we explore visualization, interaction and interface design strategies that can be re-used and adapted to different types of individual and community data and public settings. The development of the design studies involves a range of design activities such as literature review, contextual inquiry, ethnographic pre-study, design workshop, expert workshop, and iterative prototyping and probing. We discuss the decisions made throughout the design process and the rationale behind them. We implement the designs as fully functional installations that can be deployed within real-world public settings thus allowing us to evaluate them through different in-situ methods.

Rather than just extracting insights from previous literature in information visualization, ubicomp, and urban screens or just studying existing public installations, the research-through-design approach enables us to actively create and explore ideas regarding the design of interactive visualization interfaces in public settings. In this process, the design case studies that are conducted as part of this research can be interpreted as *"vehicles for research"* to investigate the idea of combining data visualization, with sensing and display technology, and to develop and assess design considerations and sensibilities (Zimmerman et al, 2007).

3.2.2. In-the-wild Evaluation

To study the impact of public visualization on awareness, discourse and participation (Q2), we largely follow an *in-the-wild* study approach (Rogers, 2011), that is, we conduct studies in natural, real-world public settings, applying quantitative and ethnography-inspired methods.

- To investigate how people react to and engage with public visualization, we instrument our installations with different means for capturing participation logs and analyze this data in combination with field observations collected in-situ,
- To study peoples' insights, interpretations and attitudes provoked by public visualization of data, we conduct and analyze semi-structured interviews, field observations and questionnaire data collected in-situ.

This evaluation method differs significantly from research undertaken in controlled lab settings. While laboratory experiments can provide an understanding of the general performance of technology in a constrained setting, the in-the-wild approach is concerned with the (social) behaviors and activities that evolve around technology artifacts, and how people interact and interpret technology in their everyday life. Studying visualization in real-world public settings, where technology design and social, physical, and contextual characteristics of spaces are closes interlinked to each other, gives us the opportunity to gain rich insights about the impact and implications of our approach and to question and validate concepts and design considerations from a holistic perspective.

3.2.3. Critical Reflection

To understand the implications for the public visualization of citizen data (Q3), we develop a critical perspective on the results of our studies and on public visualization when used to shape the opinions, attitudes and behaviors of citizens. In each of the conducted main studies, we provide a comprehensive discussion of the employed design decisions and evaluation results as to reveal useful design and study strategies, but also to uncover limitations and challenges, and to discuss future opportunities.

3.3. Overview of Studies

As summarized in Table 1, we structured our research in two parts: In Part I we conceived two design studies, *AmbientNEWS* (Valkanova et al., 2010) and *theVisitors* (Valkanova et al., 2011), that constituted an initial inquiry of what it means to design visualization of data, originating from people, and to situate it in the public settings they share, pass-by or dwell about. These initial design studies provided design and empirical evidence that served to refine the main research questions this research aimed to address. Part II formed the core of this research, including three studies, conceived to investigate the design, impact and implications of public visualization, combined with display technology and different data-sensing mechanisms as means to influence awareness, discourse and participation. Each of the studies addresses a different set of challenges: *Gurgle* studies inciting and sustaining behavior change (Arroyo et al., 2012), *Reveal-it!* investigates enhancing awareness and discussion (Valkanova et al., 2013), and *MyPosition* focuses on influencing participation and social interaction (Valkanova et al., 2014). In the following three sections we offer brief descriptions of the three studies, including research goals and installation- and study setup, and conclude each section with a succinct summary of the corresponding study results.

Table 1: Overview of the studies conducted within this research and the most relevant contributions.

	Study	**Visualization**	**Contributions**
Part I	Study1	*AmbientNEWS*	Suggestions for design and research
	Study2	theVisitors	

Part II	Study3	*Gurgle*	Proposing contextualized feedback to incite interaction and behavior change
			Proof of impact
			Strategies for variable feedback modalities
	Study4	*Reveal-it!*	Proposing social visualization to enhance awareness and discussion
			Proof of impact
			Patterns and factors for participation
			Design challenges and emerging behaviors
	Study5	*MyPosition*	Proposing identifiability and playfulness to influence participation
			Proof of impact
			Patterns and factors for social interaction
			Implications for design and use

4. *Gurgle*

In this study we explored the ability of contextualized audio-visual feedback to incite interaction and lead to sustained behavior change and examined the impact of variable feedback modalities (Arroyo et al., 2012).

4.1. The Installation

The design concept was of an embedded installation that could be experienced while walking through a shared space characterized by an intense flux of people. As a real-world test bed, we chose the crowded central corridor of a large university building. This is a transition space where people rush-by every day without taking the time to be aware of their surroundings or to relax. We aimed for a design that attracts attention of passers-by and entices them to take a refreshing drink from a water fountain in the corridor. We created *Gurgle,* an interactive audio-visual augmentation of one of the seldom-used public water fountains in the space (Figure 2). It was considered important that it fitted properly into the environment and so considerable attention was given to designing it to be aesthetically pleasing. We created an appealing, but discrete and robust interaction and physical design as to complement the space and its activities without being obtrusive.

Figure 2: *Gurgle* is an interactive audio-visual installation in a public corridor that augments the existing water fountain, with the aim of encouraging people to pause and take a drink.

Gurgle was designed to be both reliable as permanent art installation and flexible as an experimental platform. The proximity of passers-by in the corridor triggered *Gurgle* to briefly illuminate. If they stopped to take a drink, the entire nook that contained the fountain was transformed by watery reflections with sound of a gurgling stream (Figure 3).

Figure 3: *Gurgle* is designed to attract the attention of passers-by: the proximity triggers Gurgle to briefly illuminate, drinking from the fountain transforms it in watery reflections and sounds.

4.2. In-the-wild Evaluation

We conducted a long-term in-the-wild study to evaluate *Gurgle*'s impact on water drinking behavior and to compare the effectiveness of audio-visual feedback. A one-month pilot installation at an art gallery validated the appeal of the audio-visual feedback and the robustness of the technical system with 3,000 visitors. A second version was installed for nine months (including 2.5 months for baseline and accommodation) on its permanent location in a public university corridor. On average roughly 2,600 walked past the fountain daily during the summer term and 8,900 during the busier fall term.

Gurgle randomly cycled through 4 feedback modalities in 4-hour intervals: *responsive light*, *responsive sound*, *responsive sound and light*, and *no interaction* that served as the baseline for usage. Motion, distance and trigger sensors allowed *Gurgle* to measure its own impact according to three metrics: hallway activity, attracting passers-by and activating the water fountain. We applied a multivariate ANOVA using the Wilks Lambda criteria to measure change in the proportion of people using the fountain, when the augmentation was present. Furthermore, we assessed the differences in the usage proportion depending on the feedback modality by using Tukey's HSD post-hoc test. Finally, we observed the way people perceived and approached the installation by direct observation and by inviting people to give feedback through a campus-wide magazine.

4.3. Summary

We found that augmenting the experience of an everyday public shared space with simple, and aesthetically pleasing interactive representations of passers-by presence and activity can improve the perception of a space and even motivate new behaviors in a sustained way. Usage sensors integrated in the installation confirmed sustained increased usage over the whole study period. Furthermore, the cycling pattern of modalities revealed that embedded interactive representations can be more effective at engaging the public if they vary in modality and are responsive to the number of people within the space. *Gurgle* helped us reflect on the implications for public augmentation as a tool for improving perception of public space and motivating new behaviors, and discuss a set of initial design strategies to trigger interaction and support participation. More complex aspects of inciting and supporting participation were subsequently addressed in our study *MyPosition (Section 6)*.

5. Reveal-it!

In this study we investigated how onlookers would engage with a public visualization of data, originating from themselves, and in particular how such public visualization would influence their personal reflections and collective discussions (Valkanova et al., 2013). We also aimed to study how well social visualization in a public and physical context conveys an implicit message supported by exact data.

Figure 4: Reveal-it! is an interactive visualization of individual and community energy consumption. It encourages passers-by to submit their data and reflect on preconceptions about their own habits and related community issues.

5.1. The Installation

To this end we designed and developed *Reveal-it!* (Figure 4), a public visualization installation, which consists of a dynamic infographic illustration to facilitate the sharing and comparison of individual and community energy consumption data. Based on literature review and an ethnographical pre-study (Valkanova et al., 2013), we proposed social and opportunistic visual comparisons as a strategy to raise awareness, and provoke reflection and discussion. Accordingly, the visualization consists of an abstract sunburst representation, of which each burst corresponds to the energy bill reported by an individual household participant (Figure 5-Left). Upon data entry, the participant's name (if provided) appears at the end of the corresponding burst, as a comparative consumption number: *"Person X: Y €. Neighborhood X: Y €."* Each neighborhood is represented by a different color, and occupies different parts of the circular shape proportionally to the relative participation rate of the neighborhood. Our visualization shows a dynamically animated arc over each neighborhood portion in order to convey the average consumption of a given neighborhood. The arc representation also allows onlookers to compare neighborhood values to city-wide statistics.

We aimed to develop a personal, yet public form of data entry. Accordingly, the system allowed any onlooker to voluntarily input their data into the system via a mobile interface. The data form requested the participant's monthly energy expense (what she remembers to have paid for her last electricity bill), her neighborhood and the number of co-inhabitants in her household (Figure 5-Right).

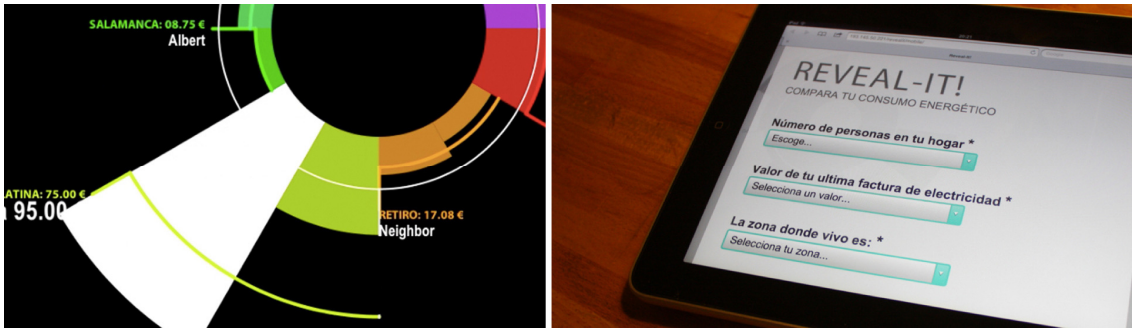

Figure 5: Left: a close-up view of the visualization part of Reveal-it!. The white burst corresponds to a participant, recently submitted their data. Right: people can submit their own energy consumption data into the Reveal-it! system by means of mobile entry.

5.2. In-the-wild Evaluation

5.2.1. Location Description

We deployed *Reveal-it!* as a public projection at three distinct public locations in two different cities over a total period of 20 days. The installation was first deployed at a public cultural center in the city center of Córdoba, Argentina (location A). The projection was installed for 16 days in a semi-open space within an open-air inner yard of the center. *Reveal-it!* was also installed in the entrance lobbies of two community centers (locations B and C) in two different neighborhoods of the city of Barcelona, Spain for one and three consecutive days respectively. The situations during deployments varied largely across locations: *Reveal-it!* was installed at location A during an annual festival about arts and technology, and at location B during a local round-table meeting about renewable energies. In contrast, location C hosted various parallel activities at the time of the deployment. In each of the study locations a mobile iPad interface was situated in front of the visualization to facilitate participation. Visitors could dwell around in the spaces, discover and spontaneously approach the visualization.

5.2.2. Observations

We observed and listened in to the visitors, capturing their initial behavior towards the projection (e.g. attention and reaction) as well as the visitors' attitudes while interacting with it, discussing among themselves, or contemplating it. To facilitate the process, we devised observational categories that were subsequently refined. In an overall period of 20 days (i.e. 144 observation hours), we took notes of about 442 (out of a total of approximately 558 visitors) unique persons who intentionally approached Reveal-it!, alone or in a group.

5.2.3. Semi-structured Interviews

Semi-structured interviews were conducted with individuals or groups, during which we also recorded demographical data, such as age and gender. The interviews included questions regarding the opinions

about the Reveal-it! in terms of its understandability and experience, as well as its potential usefulness. Visitors were also invited to freely express their suggestions and thoughts in relation to the project. Throughout the 3 study locations, we conducted 18 interviews with 86 visitors overall (47 male and 39 female), who interacted with the visualization and spent at least 2 minutes in front of it. The interviewed people ranged from single individuals or couples to groups of 20 people of approximately 15 to 70 years old.

5.2.4. Participation Logs

At all study locations, we logged the data entries of the visitors who directly interacted with the visualization (N=198). Each participation was digitally time-stamped, allowing us to later map the reported visitors' data to the overall state of the visualization at the moment of participation.

5.2.5. Questionnaire Test

To quantitatively assess how well the visualization conveyed comparative information, we conducted a post-response questionnaire test with 30 participants in the last deployment day at location C. The questionnaire was integrated in the data entry interface and shown on tablet device. The test followed a simple 2-step procedure: *Step 1. Participation*. Participants first entered their personal consumption-related data (like normally). They then observed the visualization and while still standing in front of it, proceeded to the post-response questionnaire. *Step 2. Post-Response*. Participants provided a response to the questions "Compared with my neighbors, my consumption is:", and "Compared with my city, my neighborhood's consumption is:" expressed as a 5-point Likert scale (range: much less - much more).

5.2.6. Data Analysis

We analyzed field notes and visitor opinions using grounded theory to draw bottom-up findings based on the direct quotations and to establish hierarchies and connections among remarkable findings. Apart of descriptive statistics of visitors' participation, we used the logs together with the questionnaire test data to evaluate the comparative understandability of the visualization, applying a non-parametric Spearman rank test. We further used this data to triangulate participants' comments and reactions upon participation. Table 2 gives an overview of the types of data we collected from the study.

Table 2: Overview of the collected data from the three deployment locations of Reveal-it! **At location C, we also conducted a questionnaire test with 30 participants.*

Location	Days	Observed	Interacted	Interviewed	Logs
A	16	400	344	67	172
B	1	33	33	5	28
C*	3	125	65	14	52
Total	20	558	442	86	198

5.3. Summary

Our in-the-wild deployments in three distinct informal public settings empowered citizens across locations to reflect on their own as well as their communal energy consumption issues. We leveraged our findings to propose social and opportunistic data comparisons as essential to raising awareness and provoking discussion. We also observed several challenges involved in integrating socially motivated data visualizations into the public context, such as the accuracy of understanding and the perception of trust. The study demonstrated that the ability to collectively compare data values, in particular enhanced by playful design and explicit personalization of the individual contributions could considerably support group exploration and reflection on the data. At the same time, however, the explicit expectation to submit openly one's own data may induce feelings of embarrassment, which may ultimately lead to false data entries and negating the truthfulness of the display. Lastly, our work highlighted the challenges of crafting study methods in-the-wild that are able to capture the subtleness of integrating technological means such as visualization projections to encourage an unpredictable, public discourse. Some of the most salient are the discrepancy in self-reflection and the unfolding temporal dimension of engagement with the visualization display.

6. MyPosition

In this study we investigated the potential of interactive social visualization to influence participation and deliberative discourse in public settings (Valkanova et al., 2014). In particular, we focused on how identifiability of the individual contributions as well as playful interaction and representation modalities can support or hamper meaningful participation. We also examined the social interactions caused by the visualization in its larger physical context.

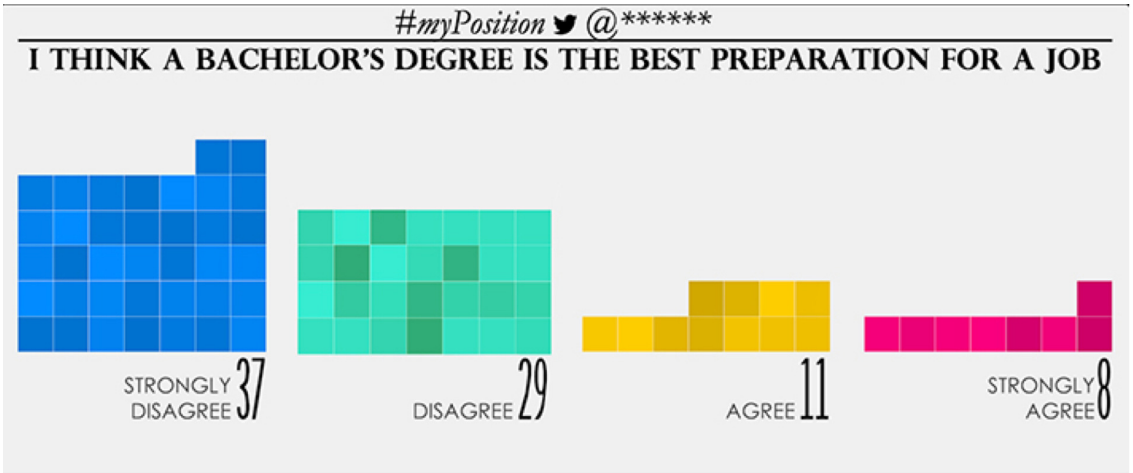

Figure 6: A snapshot view of *MyPosition*'s visualization: A tile corresponds to an individual vote (for one of the four voting options). The voting topic is positioned on top.

As part of this study, we introduced *MyPosition*, a large-scale interactive poll visualization, designed to support the situated deliberation of citizens' opinion data and the collective exploration of the resulting statistics. The visualization consists of a set of square tiles, of which each corresponds to an individual opinion submitted by a passer-by (Figure 6). Each of the preference options is represented by a different color and a textual label, and occupies an equally large horizontal section of the screen. The voting topic is shown on the top (Figure 6). An interactive participation mechanism (based on camera tracking) was developed, that allows any passer-by to express her opinion on a given topic by way of a full-body interaction method. A person is able to vote by consciously positioning herself along the display in front of a desired opinion section along a 4-point scale: 'strongly disagree'- 'disagree'-' agree'-'strongly agree'. In order to place a vote, the participant has to raise her hand (Figure 7).

Figure 7: Participation mechanism of *MyPosition*. Passers-by can choose an option by positioning themselves along the screen. Submitting a vote is facilitated through gesture-based interaction – by rasing the hand.

Furthermore, in order to explore the relationship between anonymity of the individual contributions and participation, we created three different representations of an individual opinion, each representing a different degree of identifiability: *color*, *contour*, and *image* (Figure 8). In *color* mode (low identifiability) all tiles look identical, making it impossible to identify which vote was submitted by whom. In *contour* mode each tile contain a graphical contour of the person who placed the vote, as captured by the camera. While it is difficult to identify other participants, a participant might be able to recognize her own submission. In *image* mode (high identifiability) each tile contains a photo of the corresponding participant, making it possible to identify who submitted what preference in the visualization.

Figure 8: We developed three different representation modalities of an individual opinion: *colour* (left), *contour* (middle), *image* (right).

6.1. In-the-wild Evaluation

6.1.1. Deployment Location

After conducting a pilot study at a local community center, we deployed *MyPosition* over the course of one working week in the foyer of a large university cafeteria. The deployment location was mainly visited around noon by students or staff of the TU Berlin and University of the Arts, as well as locals living nearby. The contextual setting of the space was characterized by several distinct zones: two *transit areas* situated between the main entries/exits and the dining-hall of the cafeteria; a *waiting area* in front of a coffee shop, as well as several *sitting areas* and *standing areas.* Based on previous research and our experience from the pilot studies, we situated the projection in a transit area in front of the large sitting area, to maximize potential overlapping situations for both inadvertent interactions with the installation as well as idling, contemplation and gathering in a more broader space.

6.1.2. Observations

Throughout the evaluation period we kept field notes such as simple sketches annotating the relative locations and movements of passers-by. We observed and listened in to visitors, capturing their initial behaviors (e.g. direction of movement, attention, and reaction) as well as their opinions during their interactions or while discussing among themselves. To facilitate the process, we devised observational categories that were subsequently refined. In an overall period of 5 days (approx. 30 observation hours), we took notes of about 445 random persons who noticed the projection, 356 of which (80%) were in groups.

6.1.3. Semi-structured Interviews

We approached individuals and groups of people who had interacted with *MyPosition* and/or spent at least 2 minutes in front of it. The interviews lasted from 5 to 20 minutes and were typically performed after visitors placed a vote. At the beginning of each interview, we inquired about the purpose and habits of visiting the location and their initial motivation for approaching the projection. We further asked about general voting habits, civic discussion behavior, and attitudes towards engaging in issues related to the location. We also noted age and gender of participants, and their social context (e.g. whether they came alone, in group, etc.). The interviews included questions regarding *MyPosition* in terms of its understandability, its potential usefulness, its interactivity, the representation of votes, as well as any other suggestion or thought in relation to the project. Overall, we conducted 17 interviews with 26 visitors (3 female). We attribute the unbalanced gender to the higher ratio of male students at the nearby technical university. We interviewed 9 individuals, 7 couples and one group of 3 people. The majority of interviewees were between 20 to 30 years old (except of 5 who were between 55 and 65 years).

6.1.4. System Logs and Captures

Our system continuously recorded anonymous data of passers-by and participants, such as log files, screen video captures and depth image streams. Besides the three-dimensional position data of each individual that entered the interaction zone (captured at 30 Hz), the log files contained timestamps of all relevant user events, such as: visitors entering or leaving the interaction zone; positioning themselves in front of a specific voting option; or performing the voting gesture. The screen content was captured in full resolution at 15 frames per second (fps), while the depth image streams of the sensors was captured at 30 fps. Over the course of the deployment, we collected data of about 4980 passers-by. As 80% of passers-by occurred within the core hours (12pm-3pm), our quantitative analysis is based on that time period.

6.1.5. Experiment

To quantitatively assess how the different vote representation modes affected participation, the system automatically switched between *contour*, *image*, and *color* every 30 minutes. Only votes that were placed during the current mode were presented on the screen. In order to minimize any effect of the order of options on voting, after half of the deployment time we reversed the order of the options.

6.1.6. Data Analysis

Similar to our method approach in *Reveal-it!,* we analyzed our collection of field notes and visitor opinions using grounded theory. Apart of the descriptive statistics of visitors' participation, we used the system logs together with the interview data to evaluate the impact of identifiability. We further used this data to triangulate participants' comments and reactions upon participation. Table 3 gives an overview of the types of data we collected from the deployments of *MyPosition*.

Table 3: Overview of the collected data from the two deployments of *MyPosition*.

Location	Days	Observed	Interacted	Interviewed	Logs
Pilot study	5	85	23	6	n/a
Main study	5	445	305	26	880
Total	10	530	328	32	880

6.2. Summary

The design and evaluation of *MyPosition* demonstrated that an interactive public visualization of a local concern can be a means for civic participation and discussion. An in-the-wild evaluation study revealed that (i) the increased identifiability of users positively impacted the engagement with and the

social debate around the installation, however lowered the actual voting rate; (ii) people submitted their personal opinion instead of playing around with the interactive features; and (iii) the display led to considerable discussion as well as nudging among people, in particular in zones beyond the interaction area in front of the screen. Finally, we discussed the implications for design and use of public interactive visualization as a tool for increasing civic participation and discourse. In future studies, it would be worthwhile to further investigate the impact of the context, such as the socio-demographic characteristics of the audience, and to study if such systems can be augmented with more societally grounded questions and more elaborate, qualitative ways of answering.

7. Conclusions and Future Work

7.1. Inclusiveness vs. Visual Complexity

Situating public visualization of data, originating from onlookers, implies an inclusive, scalable approach to visualization design, yet poses representational challenges. We devised scalable visualization techniques, where an arbitrary number of passers-by are able to equally contribute with their personal data and impact the visual outcome. Participation scalability supports design goals such as accessibility and inclusiveness, which are important in public settings, characterized by open-ended, opportunistic usage patterns. Yet, the specific characteristics of the visualization techniques increase the complexity and density of the graphical representation, the more people add data values. This growing complexity can have various negative effects such as losing the overview of general trends and patterns or reducing the visibility of individual contributions. A potentially unexplored challenge for public visualization designers is the scalability tension between individual contributions and entire data overviews: how can we devise representation techniques for public visualization that afford the efficient and effective displaying of a very large number of participants, yet keeping the individual detail understandable and accessible in public settings?

7.2. Intuitive Understanding vs. Rich Exploration Styles

The characteristics of public settings require a balance between choosing datasets and representations that allow for intuitive understanding, and providing richer exploration styles. Having in mind the reduced attention, short-lived interaction styles, and non-expert audience in public settings, we explored the impact of relatively simple representation techniques. We aimed to convey socially-relevant data-driven issues in an accessible and enjoyable style. While people appreciated the visual approach and its *"simplicity"* and *"clearness"*, those who seemed more knowledgeable on the issue at hand expressed concerns with different aspects of this 'oversimplification'. Some of the most salient concerns were related to the fact that the visualization did not capture the complexity of all relevant parameters and did not depict underlying relationships, which may impact the data and thus its visual communication. Others criticized the lack of more detailed data submission or the installation's failure to provide a more in-depth discussion channel. Studies have explored strategies, which balance characteristics of the location, people and content of public displays (Schroeter et al., 2012). Yet, future research could

specifically focus on strategies for balancing representation and interaction issues related to public visualization: how to offer sufficient information capacity and intuitive visual understanding, while still allowing for rich exploration styles, from an at-a-glance overview to more in-depth explorative strategies that allow a deeper sense-making or more elaborate contributions.

7.3. Playfulness vs. Meaningful Participation

A key challenge in public visualization design is striking a balance between creating an engaging interaction and supporting meaningful participation and communication. Playful design strategies such as tangible or full-body interaction can increase engagement, yet may lead to random, or merely playful behaviors, as reported in (Taylor et al., 2012) and (Fritsch and Brynskov, 2011). Less expressive strategies such as SMS-based participation can cause other issues, such as off-topic, random communication, or less on-site discussion (Schroeter, 2012). Studying an expressive, gesture-based data entry mechanism allowed us to contribute to strategies for balancing playfulness and meaningful participation in public visualization. First, it should be fairly easy and fast to contribute meaningfully (e.g. share one's data-driven opinion or behavior), while at the same time misuse should be relatively restricted.

The issue of misuse can be addressed to certain extent by restricting participation to onetime use via camera tracking, yet providing a more sophisticated solution (such as face detection) can be a problem due to ethical reasons. Second, the visible persistence of one's contribution, and the immediate visual impact of each participation can also lead to a more 'considered' behavior. Based on these insights, we are investigating new interaction devices for public data submission that combine the simplicity, anonymity and playful affordances of tangible interfaces, yet can support the necessary identifiability and thus may restrict misuse (Behrens et al., 2014). While the potential of play has been only discussed in the context of participatory urban sensing (Kuznetsov et al., 2011), and suggested in the area of Web-based visualization systems (Dörk, 2012), our results encourage further exploration of playful in-situ data dissemination and comparisons by way of public visualizations.

7.4. Trustworthiness and Self-contributed Data

Designing public visualization, based on self-contributed data has benefits but also poses challenges to validity and accuracy, which can endanger the trustworthiness of the display. One of the benefits of public visualization, originating from onlookers is that it provides an emotionally accessible, personally meaningful and social experience. Furthermore, the deliberate act of public data entry can enhance engagement, as it provides an opportunistic moment at which passers-by must dedicate their attention to the topic at hand. Yet, this approach also implies several challenges that can influence validity and in turn the perceived trustworthiness of the visualization, besides impact factors such as professional appearance of the material, clear identification of the data sources, or showing associations with a trustworthy organization, suggested by (Vande Moere et al., 2011). Such challenges can be (i) *internal* e.g. the inaccuracy of self-report; (ii) *data-related* such as neglected confounding parameters (e.g. distinct habits, season cost fluctuations, or time spent at home), and excluded datasets; or (iii) *social* e.g. the public act of participation, the identifiability of the contribution, and induced peer-pressure. Future

research in public visualization could focus on questions as around the selection of the data sources, the dimensions to visualize, or the aggregate visualization techniques, as an unbalanced choice might lead to ambiguity of the representation and reduce the trustworthiness.

7.5. Public Sharing, Viewing and Comparison of Data

The in-situ sharing, viewing and comparison of personal and community data implies several data-related, social and ethical challenges. In addition to the 'social awkwardness' suggested by previous literature on public screens (Brignull and Rogers, 2003), engagement with public social visualization can suffer from hindrances that relate to the data, such as fear of inaccurate submissions or submitting values that will stand out. While effective for enticing overall curiosity and situated debate, an increased identifiability of the individual data contributions can amplify this negative effect and may subsequently detain people from contributing. Furthermore, the visibility and identifiability of others' contributions can encourage unexpected, potentially undesired social dynamics. Most salient examples are *stigma*, i.e. the public criticism of 'data outliers', both the ones, already depicted in the visualization, as well as potential participants in the communities they were part of, or *social nudging*, i.e. the act explicitly prompting peers towards participation, and possibly certain behaviors.

This calls for attention towards the social and ethical challenges involved in the de- sign of public visualization, aimed at the general public, rather than small co-located groups such as in (Greenberg and Rounding, 2001; Huang and Mynatt, 2003). Situations of submitting personal data about an issue, implicitly related to the institution hosting the display, may lead to a more conformist behavior, when it comes to an open criticism. Social groups and communities, who - intentionally or not - do not take part of the visualization, might still be affected due to the uncontrolled social discussion and reflection. Lastly, while the open debate is a desired result, those who are less inclined to publicly submitting their personal data, may be even inhibited to express their views, when social pressure towards the 'correct' contribution is induced. How would people's own contribution be effectively influenced when others' are readily visible, is still an open question. Future studies could also explore how the explicit choice of identifiability may influence one's participation behavior.

7.6. Understanding Engagement with Public Visualization

Understanding engagement with public visualization, as it emerges within causal, opportunistic rhythms and routines, is essential to creating adequate evaluation goals and methods to measure them. We observed that engagement with public visualization emerges through patterns of unfolding depth, ranging from immediate responses to interactivity and visual appearance, explorative interactions (i.e. how the visualization works and performs), to higher cognitive or social processes such as sense-making, reflection and social discussion. It is well known that prominent visibility (Hinrichs et al., 2008) and presence of others (Brignull and Rogers, 2003) attracts attention and evokes initial curiosity to public displays. However, we discovered that the actual engagement with an underlying topic involves a temporal flow, namely (i) first to realize that the display is a visualization, then (ii) to understand what the visualization is about, and finally, (iii) to understand how to relate to the presented information. Only

after active involvement and reflection, people can (iv) adopt a more critical perspective towards the visualization and its implications.

While several frameworks for engagement with public displays have been discussed (Brignull and Rogers, 2003; Vogel and Balakrishnan, 2004; Dalsgaard et al., 2011; Michelis and Müller, 2011; Memarovic et al., 2012; Behrens et al., 2013), future studies could explore defining and modeling engagement with public visualization in particular. More work needs to be also done in crafting in-the-wild evaluation methods, capable of capturing and describing the unfolding depth of comprehension or the subtleness of contemplative, reflective or discursive activities related to public visualization.

7.7. Discrepancies in Interpretation

The subjectively different interpretations of personal data versus the data of others pose a challenge for evaluating the impact of public, user-driven visualization in a social context. When experienced in-situ, people seem to perceive and interpret visual comparisons of their own data differently for the different visual extremes, in particular when a 'correct behavior' is implied. Poor performers tend to assess their comparative values less accurately in comparison to good ones. Furthermore, personal data (and the underlying causes of it) is mostly interpreted through the lens of individual behavior patterns or personal circumstances. In contrast, aggregate community data is interpreted in the context of external factors (e.g. utilities, infrastructure, legislation).

Theories from social science and psychology can hint to the sociocultural background of the observed discrepancies. Research in psychology, for instance, has demonstrated that people would try to recognize themselves, and subsequently report about their result more positively than in reality, especially when social comparison is involved (Festinger, 1954). Social scientists have argued that the perceived *"locus of control"* (e.g. whether a certain result is under one's own control or external factors) can strongly impact perception of one's own behavior influence, and subsequently affect motivation (Rotter, 1966). It is still an open question whether public visualization systems actually succeed in questioning or reinterpreting, or just affirming the self-image of onlookers, and how evaluation methods can accurately capture such phenomena.

7.8. From Public to Urban Visualization

Expanding the concept of situated visualization of citizen data from the public in-door to the outdoor urban context brings new challenges and opportunities from methodological and design perspectives. While this research explored how urban technologies for sensing and display can support the public visualization of data, our empirical results have been obtained predominantly in indoor, or semi-indoor public settings. Research in media facades have already discussed several challenges related to the integration in physical structures and surroundings, increased demands for robustness and stability, and the possibly unforeseen diversity of situations (Dalsgaard and Halskov, 2010). Yet, a potentially unexplored field for design and research is the understanding, addressing and conceptualizing the

challenges specifically related to the urban visualization of data. The growing affordability and diversity of digitally addressable light structures opens up opportunities for exploring data-driven communication at a much larger scale and visibility, and offers new aesthetic possibilities beyond the traditional screen (Behrens et al., 2014).

However this new 'pixel paradigm' alters the concept of resolution and light, and can pose challenges on designing for understandability and information capacity. Day-light conditions in urban space also create limitations for certain display technologies, calling for attention towards alternative, non-digital or mechanical materials for depicting visualization, capitalizing on the potential of material tangibility and transience (Koeman et al., 2014). Yet, how important issues such as updateability, scalability and participation can be addressed in this case, would be an open question to tackle. Lastly, urban visualization, as well as urban interaction design in general, should continue and deepen the dialogue with disciplines with longer tradition in exploring the urban domain such as architecture (Ishikawa and Silverstein, 1977), urbanism (Jacobs, 1961) and sociology (Goffman, 1963). Contributions by Greenfield (Greenfield, 2010) and Fatah gen. Schieck (Fatah gen. Schieck et al., 2013) exemplify some of the opportunities of this dialogue from conceptual and methodological perspectives.

7.9. Towards An Ecology of Public, Social Interfaces

Envisioning public visualization as a vehicle for situated, contextually meaningful communication, publicly visualized data should reflect the particular values and circumstances of the people, buildings, or activities within the local environment. To transmit a direct and immediate relationship to the local context, we chose an approach where the data is sensed or acquired within the physical environment immediately surrounding the display. We specifically explored situated data input modalities, ranging from implicit activity sensing, to mobile entry or gesture-based interaction. While this approach provides people with an opportunistic, immediate engagement with their own data, future studies in public visualization can explore other services and interfaces for data collection, in addition to the situated data entry. Civic issues such as air pollution, crime, council expenditures or traffic can also benefit from social public visualization, by contextualizing relevant data, originating from governmental organizations (e.g. open data archives) in the public sphere. In addition, public visualization could be complemented with other citizen-driven forms of data collection and sharing, for instance by interfacing participatory sensing kits and services (such as Smart Citizen Kit[c] or Pachube[d]). Combining situated means for visualization, with both top-down and crowd-sourced platforms could potentially contribute to an integrated public ecology of interfaces for social or political communication and constructive feedback among urban stakeholders, such as citizens, urban hackers, governmental and advocacy groups, and the media. Yet, how critical notions such as transparency, plurality, contingency and empowerment (Dörk et

[c] The Smart Citizen Kit. www.smartcitizen.me
[d] Pachube. http://www.haque.co.uk/pachube.php

al., 2013) would be defined and negotiated in a public participatory context will be an open issue to address.

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