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Beyond quantification: a role for citizen science and community science in a smart city

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When approaching the issue of data in Smart Cities, there is a need to question the underlying assumptions at the basis of Smart Cities discourse and, especially, to challenge the prevailing thought that efficiency, costs and productivity are the most important values. We need to ensure that human and environmental values are taken into account in the design and implementation of systems that will influence the way cities operate and are governed. While we can accept science as the least worst method of accumulating human knowledge about the natural world, and appreciate its power to explain and act in the world, we need to consider how it is applied within the city in a way that does leave space for cultural, environmental and religious values. This paper argues that a specific form of collaborative science – citizen science and community science – is especially suitable for making Smart Cities meaningful and democratic.

When approaching the issue of Smart Cities, there is a need to discuss the underlying assumptions at the basis of Smart Cities and challenge a prevailing assumption that efficiency and productivity are the most important values (Su et al. 2011, Chourabi et al. 2012, Greenfield 2013, Nam & Pardo 2011). We need to ensure that human and environmental values are taken into account in the design and implementation of systems that will influence the way cities operate.

A good starting point is to notice how the image of the city is portrayed within the Smart Cities discourse. Throughout history, the image of the city has alternated between the tamed and feral, order and chaos, natural or engineered. The Smart Cities paradigm seems to play on many of these aspects, sometimes using the inherent contradictions to promote investment and political support of a specific development path. For example, we find ourselves progressing from the proliferation of Closed Circuit Television (CCTV) cameras (Coleman & Sim 2000) to networking the feeds from multiple cameras and the integration of image processing such as number plate or face recognition software (Graham 2005), all in the name of improving security and efficiency. More broadly, the path of Smart Cities is about the application of information and communication technology, environmental sensors, digital footprints of the inhabitants, manipulation of the resulting data using statistical techniques, and use of complexity modelling and advanced visualisation to make sense of it all as a new paradigm for the operation of cities. These assemblages aim to promote efficiency, productivity and safety and reduce uncertainty in the management of places. But is that a future that we would like to live in? Do we envisage a future where efficiency is more important than human encounters, or uncertainty is reduced so much so that serendipity will diminish with it?

Too often, proponents of technology suggest a future in which we are 'all watched over by machines of loving grace' (Brautigan 1967), assuming that the societal impacts of technology are only benign and beneficial while technology in itself is value neutral. Yet, as many discussions in the philosophy of technology and elsewhere in critical studies of technology show (e.g. Feenberg 2002, Dusek 2006), the creation and maintenance of technologies encapsulates specific values and can lead to 'black boxing' of ideologies and concepts of how society should run. This is especially true for software codes (Kitchin & Dodge 2011), such as those proposed in the Smart Cities paradigm, which are presented as 'merely efficient algorithms' while being a representation of specific abstractions and thinking about the way cities and societies function. Notice that, in the case used above, the locations of the CCTV cameras and the direction of the development of image processing algorithms represent a specific conceptualisation of which places are worthy of protection and order and who is defined as a threat to society.

Knowledge, information and data are the ingredients that link the computational side of the city to reality. Of these, data are the most basic and emerge from sensors in the city – both from devices that are used by the people in the city and various environmental sensors that are installed across it, such as the CCTV frames. Just as with the algorithms, we need to remember that data are not neutral, objective or natural. As Checkland and Holwell (1998) remind us, information is not made of data but from capta – facts that are actually collected from the real world. This is in contrast to data – potentially all the facts about the world, many of which we ignore or cannot collect. Dodge and Kitchin (2005) trace back the concept of capta to Jensen (1950) and note: '… capta are units of data that have been selected and harvested from the sum of all potential data. Here, data (derived from the Latin *dare*, meaning "to give") are the total sum of facts that an entity can potentially "give" to government or business or whomever is constructing a database. Capta (derived from the Latin *capere*, meaning "to take") are those facts that those constructing the database decide to "take" given that they cannot record or store everything. … Capta are inherently partial and selective, and the distinguishing criteria used thus have consequence' (p.854). As a result, the information that is created from these capta, and the knowledge that is built on the back of the information, is, by necessity, a biased and partial view of the world. For the sake of readability, the term 'data' will be used in the rest of this paper, while it is inherently understood to be 'capta'.

Moreover, there are deep epistemological and ontological problems with pure quantitative studies of society through algorithms, statistical analysis and mathematical modelling, which are promoted in the Smart Cities paradigm. Many of these problems were discussed in the wake of the first 'quantitative revolution' in social sciences in the 1960s and 1970s. In many ways, we should view the current paradigm as an attempt for a 'quantitative revolution 2.0', and much of the critique that is applied to Smart Cities (e.g. Greenfield 2013) resonates with previous critique within geography and urban studies of analysis that focus too much on quantification in the belief that it will make the city 'knowable and controllable' (Kitchin 2014).

Yet, given the technological advances that are enabling the Smart City – increasing availability of sensors, access to mobile devices that are connected to communication networks throughout the urban space, and an increasing number of people who are accustomed to data collection and sharing – then **how we can ensure that the computing and sensing abilities that are being developed are integrated with meaningful and purposeful community activities?** This question is at the centre of this paper, paying special attention to the meaning given to the data that is collected. This is done by looking at the concepts from philosophy of technology and, in particular, the ideas of Albert Borgmann (1984, 1999, 2010) about the nature of information and data. In particular, we will look at the *Device Paradigm* and *focal practices*. Using these concepts, we can see how data collection activities within participatory sensing, which can be interpreted as part of the apparatus of a Smart City, can become more meaningful and complete by emphasising the social practices more than the technical, quantitative activity.

The Device Paradigm and Focal Practices

In the early 1980s, Albert Borgmann identified that modern technology tended to adopt the myopic 'Device Paradigm' in which specific interpretation of efficiency, productivity and a reductionist view of human actions were taking precedence over 'focal practices' that bring people together in a way meaningful to human life. For example, while a Facebook textual message is a way to create a fleeting communication that demands attention from the sender and the receiver for a fraction of time, meeting a friend for coffee and paying full and complete attention to mutual needs for a chunk of time is more fulfilling of the human need for companionship and social interaction. By thinking that the only interaction that happens during a meeting is communication, it is possible to argue that social networking over the web offers a more 'efficient' way of maintaining social links. As Sherry Turkle demonstrated in her recent *Alone Together* (2012), this reductionist view of social interaction is missing the point and, indeed, meaningful social relations are being lost by relying on information and communication technology (ICT) as the main conduit for social relations.

Borgmann's analysis is especially important to the question of technology and the city, since he frames his investigation with the effort of developing meaningful and fulfilling human life – addressing the age-old philosophical question of 'the good life' within technological societies (Higgs et al. 2000, Verbeek 2002). He notes that modern technology operates by disburdening human effort from activities that are laborious and turns them into commodities. Thus, a hearth, which requires the wood supply to be ensured, the fire to be attended and regular cleaning, is replaced with central heating, now controlled remotely from an app on a smartphone. While the very narrow result of 'warm and comfortable room' is achieved with both technological settings, something more profound happens. The hearth is a 'thing' that requires attending to and effort, but it also belongs to the group of objects and activities that can be termed 'focal thing' – things that facilitate wider human activity and make sitting in front of the fire especially meaningful in comparison to the 'device' of central heating, which is unnoticed and makes its services commodified and easily accessible. Importantly, this move from 'things' to 'devices' is changing the way people relate to reality. Some of the 'focal things' facilitate 'focal practices' such as getting together in the evening in front of the hearth and having a conversation about the events of the day – something that is lost with the convenience and availability of the heating. The Device Paradigm is therefore the generalised trend in which technology promises to enrich and disburden people's lives, but instead takes away a fuller engagement with reality.

With ICT, the Device Paradigm is increasing and, as the social networking companies have demonstrated, once other aspects of human life have been commodified (heat, housing, transport, communication), human relationships themselves are now being seen as ripe to be reduced to their technical essence and monetised. This was predicted in Borgmann's (1999) differentiation between natural and cultural information, which belongs to focal things and practices, and technological information, which, like devices, misleads us to think that, because it is available and easy to access, it makes the world knowable and controllable. In fact, technological information obfuscates our ability to understand the world and to deal with it in a meaningful way (see Sieber & Haklay forthcoming). Within this analysis, much of the 'Big Data' that the Smart City assumes to be using makes reality more difficult to grasp, since 'nothing any longer presents itself with any authority… Anything might as well be an impediment to inquiry' (Borgmann 1999, p. 177).

It is important to note that Borgmann's analysis is not nostalgic or suggesting that we destroy our central heating systems. What he emphasises is that we can consider how technology is altering life and then find the ways to protect or restore the focal practices and things that we have lost. This opens up the possibility to reform technology and to allow wider social discussion about its future directions and applications (see Feenberg 2002, Haklay 2013).

Data Creation as Focal Practice in Citizen Science and Participatory Mapping

Taking into account Borgmann's analysis, we can turn our attention to the myriad ways in which cities are offering opportunities for deeply meaningful, yet 'inefficient', human encounters – and therefore we should be careful of the assumptions that we put forward, and integrate, in the development of technologies that will influence them.

So can we nurture these connections and keep aspects of the Smart Cities agenda, maybe by subverting it or using the data resources that are being opened? One such way is to use this assemblage of sensors, data sources and algorithms to address problems and challenges that individuals and communities face within cities – from those wishing to practise urban agriculture, monitor pollution or address energy use. We can bring back agency and control through the use of citizen science, in which non-professional researchers are involved in the scientific process. We can envisage groups coming together in an inclusive and open way, discussing the issues that they would like to address and using existing sources of data combined with their own reporting and analysis to address them.

The emergence of community/crowd/user-generated digital maps (Haklay et al. 2008) is providing some of the evidence for activities that, at their worst, fall into the trap of the Device Paradigm and at their best demonstrate the potential of new focal practices that are facilitated by technology. Projects such as OpenStreetMap (Haklay & Weber 2008) exhibit complex relationships between the contributor to the mapping product and the user of the map in terms of their understanding of the data, as well as making decisions about what will be captured and how.

For the mapper, who is commonly interested in her local area and walks through it to record specific objects, the process of mapping is an example of a novel way of engaging with the world (Budhathoki & Haythornthwaite 2013). In a project such as OpenStreetMap, in which mappers state that their affiliation to the project is linked to the project's goal, which is the production of a freely available accurate digital map of the world (Budhathoki et al. 2010), this is especially true, although there is some evidence that people who update Google Map Maker are also doing so because they identify an error in the map in their local area and are concerned with the way it is represented to the world. The process is about creating an empirical representation of reality in digital format, of identifying a road or amenity in reality and creating a representation of it using the coordinated information from a GPS receiver or identifying objects on detailed satellite images and describing them. Moreover, for the mappers themselves, the process of mapping can become a focal practice. While a very small minority of the total volunteer mapper community attends meetings, for those who contribute significantly to these projects, face-to-face meetings and discussions about the practice of mapping are significant and meaningful events. Arguably, even the unruly and often impolite discussions on the projects' 'Internet Relay Chat' (IRC) channel or on mailing lists demonstrate the level of meaningfulness that the activity plays in the life of the mappers. The act of mapping itself can be an act of asserting presence, rights to be heard or expression of personal beliefs in the way that the world should evolve and operate (see Gerlach 2015).

Even the solitary activity of a mapper, or a citizen scientist, can be deeply meaningful and transformative, as Russell (2014) described so vividly. Russell shared her experience of deciding to study an unknown detail about the life of Tiger beetles by studying them in the Gila river, near her home. The tasks that she took upon herself (and her family) included chasing beetles and capturing them, growing them in terrariums at home, dismembering some and analysing them under a microscope and so on. This quest was sparked by a statement from Dick Vane-Wright, then the Keeper of Entomology at the Natural History Museum, that *'You could spend a week studying some obscure insect and you would know more than anyone else on the planet. Our ignorance is profound'* (p. 15). This, of course, is not only true about insects, or animals, but also the night sky, or our understanding of urban air pollution. Russell explored many other aspects of citizen science, from online activities to observing the changes in nature over the seasons (phenology) and noticing the wildlife footprints in the sand. Her love of nature in her area comes through in the descriptions of her scientific observations and also when she describes a coming storm or other aspects of her local environment. In her journey, she has overcome difficulties, from following instructions that seem obvious to scientists, to figuring out what the jargon meant, to the critical importance of supportive mentoring by professional scientists. Clearly, and as her book title expresses, citizen science is a focal activity for those who participate in it.

This can be true even for what might seem, at first sight, to be the epitome of the Device Paradigm within citizen science activities – volunteer computing. Volunteer computing – the act of participating in a scientific project by downloading and installing software that utilises unused processing cycles of a computer or a smartphone – is an automation of the process of participating in a scientific project. Inherently, the level of engagement of the participants is assumed to be very low – merely downloading a piece of software, configuring it once in a while, and not much beyond. Since 2010, I have been volunteering through the IBM World Community Grid (WCG) project, as a way of experiencing volunteer computing on my work desktop, laptops and later on my smartphone, while contributing the unused processing cycles to scientific projects. Out of over 378,000 participants in the project, I'm part of the long tail – ranking 20,585. My top contributions are for FightAIDS@Home and Computing for Clean Water projects (Figure 1).

The operation of WCG turned my volunteering into a 'device'; it disburdened me from actively dedicating time to support the project. From time to time, I notice the screensaver on my computers and am pleased to see the IBM World Community Grid icon on my smartphone in the morning, knowing that it has used the time since being fully charged for some processing. I also notice it when I reinstall a computer, or get a new one, and remember that I need to set it going. I don't check my ranking, and I don't log-in more than twice a year to adjust the projects that I'm contributing to. So all in all, I have self-diagnosed myself to be a passive contributor in volunteer computing. Moreover, in comparison to Russell's experience, the participation in the project has not been focal practice for me (see also Nov et al. 2014).

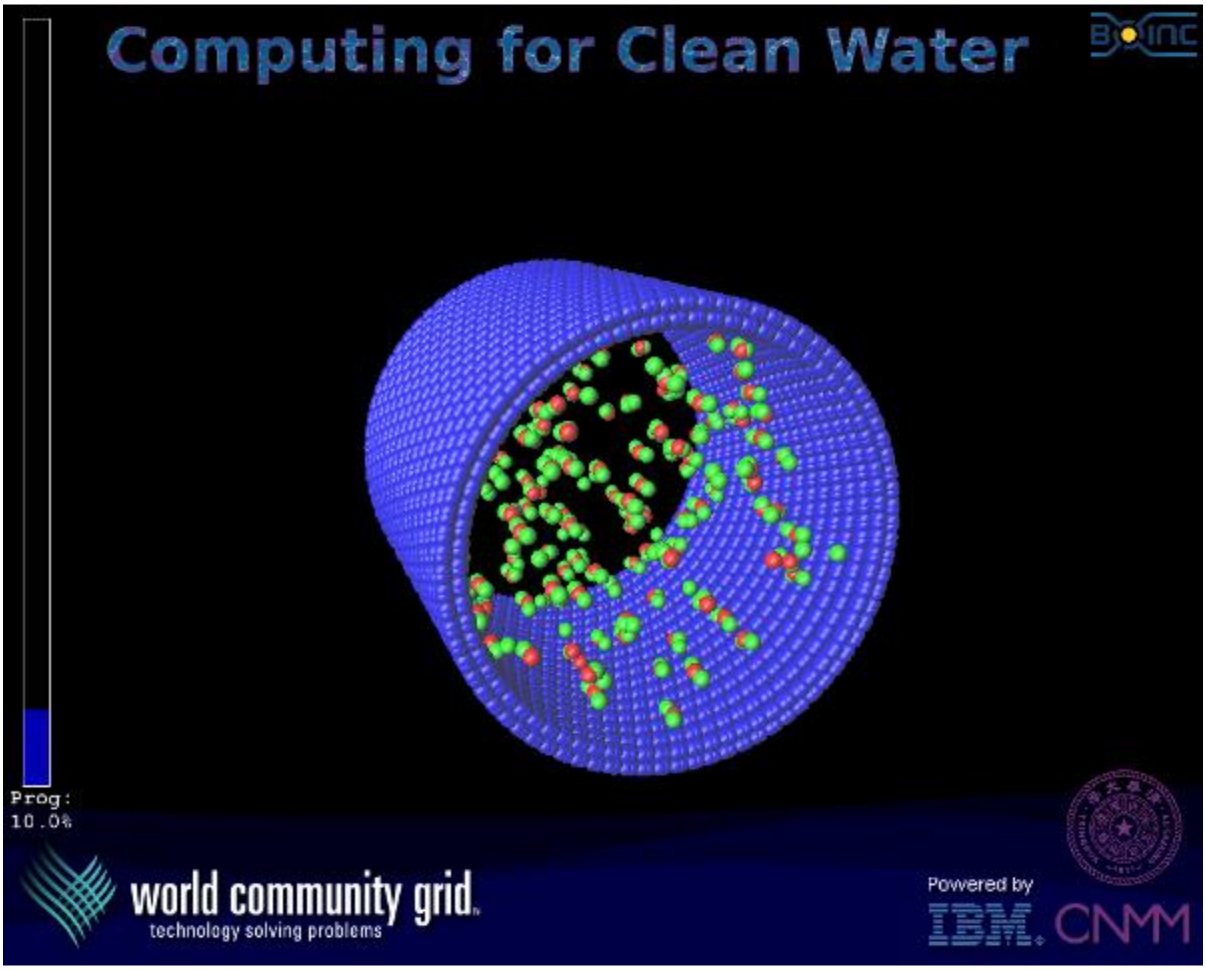

Figure 1 – Computing for Clean Water Screensaver

But then came the downtime of the project on 28th February 2015. There was an advanced message, but I missed it. Looking at my computer during the afternoon that day, I noticed a message 'No Work Available to Process'. After a while, it bothered me enough to check the state of processing on the smartphone, which also was not processing anything. A short while after that, I searched the internet to find out what was going on with the system and, after discovering that the main site was down, I continued to look around until I found the Twitter message announcing the scheduled maintenance. Even after discovering that it was all planned, I couldn't stop looking at the screensaver from time to time and was relieved when processing resumed. What surprised me about this episode was how much I cared about it. The lack of processing annoyed me enough to spend over half an hour discovering the reason. Arguably, for that afternoon, volunteered computing was elevated from a device to a focal thing. This, however, was a fleeting moment within the overall engagement.

Part of the difference between Russell's deep engagement and my fleeting one can be associated with the nature of the data and information that is produced. For Russell, data was captured through the intimate connection with the Tiger beetles that she followed around the river bank, or by observing the seasonal changes in her area. In contrast, in the WCG projects that I contribute my computer's time towards, I have no control over the data that is produced, nor will I have any ability to scrutinise it. It is created following the algorithms that scientists set, and they are the ones who have access to them and are able to control the data and its use. Part of my superficial engagement with the scientific projects that I'm involved in within WCG can be linked to this lack of relationship with the fundamental data that are produced in it.

DIY Science as Focal Practice

Beyond the individual engagement that we have explored so far, the city is also a place for collective action and communal activities, with good potential for developing new focal practices around data collection, processing and use. The degree to which users of existing technology are allowed to change the meaning of using it, or apply it to other issues from which it was designed for (Haklay 2013) is central to its potential to serve as a 'thing' and not only as a 'device'. This is especially true in the area of Do-It-Yourself (DIY) science.

DIY science is emerging from the same technological trends that are making the Smart City a possibility, but with a fundamentally different ethos, attention and processes. The continuing decrease in the cost of electronics and sensors has enabled people from all walks of life to access and use devices either within embedded commodified devices, or as components that are ready for prototyping and experimentation. Consider, for example, the sensing ability of an average smartphone. It is, in effect, a sophisticated sensing machine, with sensors for sound (microphone), visible light (camera), location (GPS receiver), direction (compass), speed of movement (accelerometer), air pressure (barometer) and many other functions. As happened in industrial processes, as smartphones became widespread, the costs of sensors dropped and they became widely available, and it is possible to find a GPS chipset for less than $3. Sensors also emerged in other industrial activities, such as the automotive industry and office machinery, and these also increasingly became cheap.

These components provide the basis for new forms of DIY electronics, in which participants use open source licences, procedures and tools to share knowledge about the development of devices that can sense and act in the world. Combined with the growing availability of small-scale and local manufacturing facilities (known as Fab Lab, Makerspaces and Hackerspace), technically able participants are able to construct from these components affordable sensing devices. The practice of sharing the code that drives the devices, as well as the blueprints of the sensors, allows other people to take existing designs and adapt them to their own needs.

A demonstration of this new ability to design cheap sensors and then use them to collect data about urban environments is provided by the Public Laboratory of Open Technology and Science (Dosemagen et al. 2011, Wylie et al. 2014), known as Public Lab for short. Born out of environmental activism that was started with the 'Deep Horizon' oil spill, Public Lab mixes virtual and physical communities of interest, in which members develop tools that can be used by any community to monitor different types of pollution, as well as carry out various scientific investigations. Public Lab activities focus '*on "civic science" in which we research open source hardware and software tools and methods to generate knowledge and share data about community environmental health. Our goal is to increase the ability of underserved communities to identify, redress, remediate, and create awareness and accountability around environmental concerns. Public Lab achieves this by providing online and offline training, education and support, and by focusing on locally-relevant outcomes that emphasize human capacity and understanding*' (Public Lab 2015). In practice, they rely on open hardware and software in which both the blueprints (in the case of hardware) and the code are available for anyone, free of charge, and open to modification. The technologies that they are developing are inexpensive (many well below $100) and, recognising that not every community or individual would want to build the tools from scratch, they sell kits that can be used with detailed instructions provided on the web. Finally, they encourage members to share their experience in developing tools through 'research notes' on the organisation's website, as well as during an annual gathering that is called 'barn raising' after the communal practice of building a barn together.

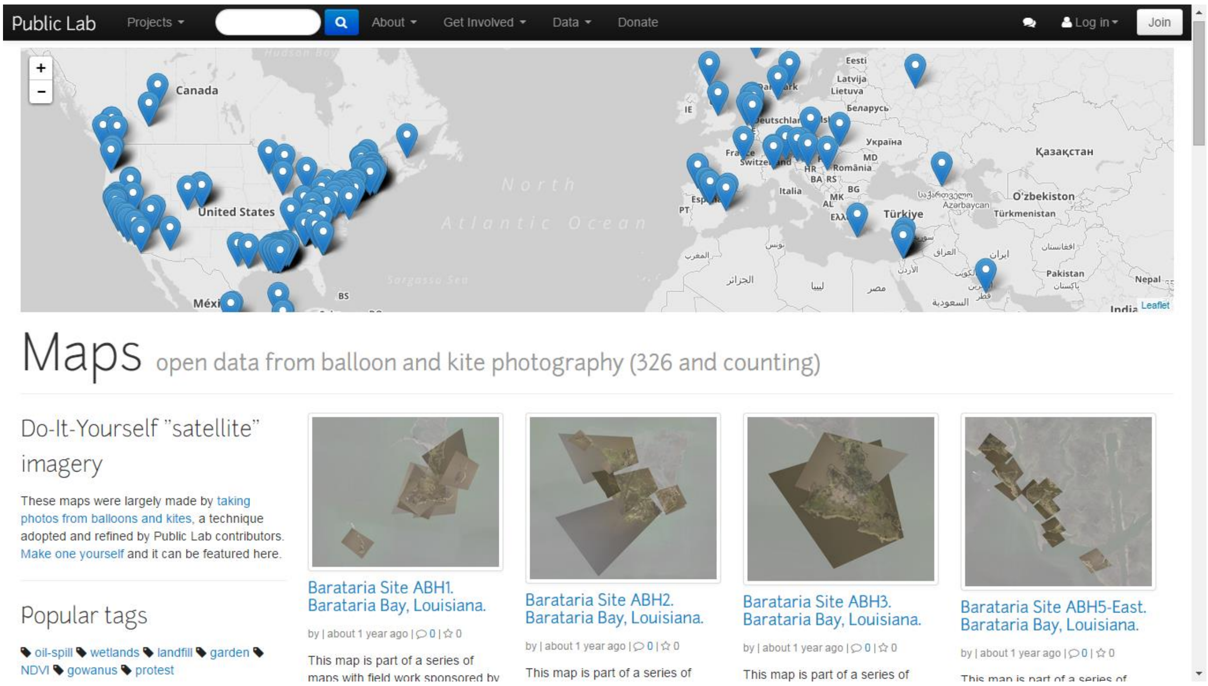

Figure 2 – Public Lab map archive

A major theme of Public Lab activities is the development of very cheap aerial imagery tools. These enable participants to use a standard digital camera, plastic bottle, strings, and balloon or kite to take highly detailed aerial photography. After the flight, images are stitched together and linked to existing geographical information using the software 'Map Knitter' and then can be used for printing paper versions or sharing over Google Maps. As members of the Lab emphasise, the value of mapping with balloons and kits where the operator is tethered to the data capture device is a demonstration of transparency, in contrast to the hidden operators of CCTV, satellites or drones. This makes the act of capturing imagery itself a purposeful demonstration of civic data collection activity. The process of selecting images that will be used to create the mosaic, stitching the images and annotating the resulting maps was designed with tools to ensure that the data and information are owned by those who created them as well as expressing the message that they want them to convey. Thus, the balloons, cameras and software that are used within Public Lab activities are clearly creating new focal things and practices.

Another example that demonstrates the potential of both 'meaning hacking' and 'deep technical hacking' (see Haklay 2013) to enable focal practices is provided by community noise monitoring around Heathrow, which was carried out within the EveryAware project (Becker et al. 2013). In this activity, the process started with an app that utilises the sensing abilities of a smartphone. The app, WideNoise, records the level of sound in decibels (dB) and several qualitative observations by the participants (such as the emotional scale of love/hate and adding a description through tagging), in addition to location and time information from the phone. A test in an acoustic laboratory demonstrated that the app could be inaccurate (in some phones by over 20 dB) and therefore only suitable for an indication of the noise as low, medium or high, but could not be relied on in terms of the dB value. Once the app was presented to a community organisation in the area of Heathrow, its use was welcomed with enthusiasm. While all the participants were aware of the limitation of the device in terms of sound measurement, the activity of going out and recording incidents of airplane noise with tagging that express emotional response to the noise was considered a meaningful one. In turn, they have used their effort as evidence of the level of community concern to put to a governmental committee considering the expansion of the airport. Thus they use the app and the devices with no alteration to the technology but to the meaning that is put into the resulting information.

Within this episode of community-led data collection, the potential of new devices based on DIY electronics was discussed with the community (Nold 2015). Among the proposed devices was a noise meter that is programmed to send a Short-Messaging-System (SMS) message every time the level of noise breaches a predefined value, which can be used to alert a local or national decision maker to the event. While the devices on offer were created as prototype interventions to spark a debate (see Nold 2015 for a full discussion), they have led to interest within the community to construct a noise monitor that is accurate enough (within less than 2-3 dB from calibrated meters), can be installed in their attics and can record the nuisance throughout the day in a way that can attribute it to specific flight events. The effort of constructing the device and considering its installation are ongoing, but it is an activity in which data collection and analysis are seen as part of wider community concerns.

Both aspects of the process – the use of the WideNoise app and the development of a noise monitor – demonstrate that, even in more minor participatory sensing events, the devices can act as a 'focal thing', bringing people together towards a purposeful and meaningful social activity that is significant to the participants.

Towards Meaningful Data Production

In this paper, the Smart Cities paradigm is challenged through Albert Borgmann's philosophy of technology, and the shortcoming of relying on data and sensors over participatory sensing activities was questioned through the exploration of the Device Paradigm.

The examples of mapping, citizen science and DIY science, as well as further examples that are emerging throughout the world, demonstrate that the potential for reviving focal things and practices through the reconfiguration of technology and its social role is possible. To achieve these goals, and make the Smart City socially meaningful, requires technical support and active intervention by those who develop the technologies or hold the know-how to use data sources and turn them into useful information. Importantly, getting together to develop technologies, discuss data collection protocols or understand the analysis can provide meaningful communal events that can nurture new and existing links between individuals and communities.

Although these citizen science approaches can potentially develop new avenues for discussing alternatives to the efficiency and productivity logic of Smart Cities, we cannot absolve those with most resources and knowledge from responsibility. There is an urgent need to ensure that the development and use of the Smart Cities technologies that are created is open to democratic and societal control, and that they are not being developed only because the technologists and scientists think that they are possible.

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