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Participatory Sensing: Recruiting Bipedal Platforms or Building Issue Centred Projects?

Christian Nold and Louise Francis

11.1 Introduction

In the last decade, participatory sensing has gained importance by aiding scientific research and supporting urban decision-making as well as emergency disaster response. This approach has many names: participatory sensing (Burke et al. 2006), urban sensing (Campbell et al. 2006), citizen sensing (Paulos et al. 2009), human-in-the-loop (Sheth 2009), human-centric sensing (Srivastava et al. 1958), people-centric (Eisenman et al. 2006) or community sensing (Krause et al. 2008). There are also many overlaps with the literature from citizen science (Silvertown 2009) and crowdsourcing (Brabham 2008). This paper focuses on the application of participatory sensing in the context of environmental monitoring. Classically, environmental monitoring functions to support policy and decision-making, via highly calibrated sensor stations that autonomously collect data about the environment. In contrast, participatory sensing promises mass participation of the public, who use their own hardware to collect large quantities of somewhat lower quality data. There are now a number of established academic fields that examine the technical challenges of this type of sensing, in particular how to maximise data quality and quantity. In contrast, the role of the participants, their recruitment and the methods for managing sensing campaigns are rarely discussed or analysed in the literature. In particular, the amount of work involved in setting up sensing campaigns and the impact of particular campaign choices are frequently downplayed. The goal of this paper is to analyse and reflect on the assumptions of participatory sensing via an empirical case study.

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11.1.1 The Assumptions of Participatory Sensing

The starting points for this paper are a series of implicit assumptions of participatory sensing. The statements are broad brushstrokes that synthesise the way in which the literature conceptualises the role of participants and the suggested methods for dealing with them. The practicalities of participatory processes are important to us since we are both participatory practitioners who have initiated and managed large scale community sensing projects with thousands of participants over the last decade. As well as this practical experience, our analysis also builds on a social science perspective that has been examining scientific work within laboratories but is now paying attention to the environmental practices of science involving volunteers (Ellis 2011; Lorimer 2008). The reason we focus on the assumptions of participatory sensing is that they are very important in dictating the scope of this practice, yet they are not openly discussed. The assumptions describe a blinkered technology-centred notion of participatory sensing, which we argue, misrepresents the actual sensing practices that take place on the ground with participants. The aim of this paper is not to make a case for humanist sensing but to present a pragmatic and realistic portrayal of the complex interactions between humans and technologies. In the act of summarising the assumptions we will inevitably loose some of the exceptions and nuances of these arguments. However, we hope that by identifying them in an explicit way, we can start a discussion about the kind of participatory sensing that we need in order to build a more inclusive and sustainable future.

11.1.1.1 Everybody Has a Smartphone

A key argument used throughout the participatory sensing literature is that smartphone adoption is growing everyday and that they are now ubiquitous across the world. The literature re-uses a range of estimates, including the estimate that there are now one billion mobile phones in use globally (Honicky 2011; Resch 2013; Tilak 2013). The argument is that smartphones have increased computational power (Boulos et al. 2011), network connectivity and flexible data plans as well as embedded sensors, such as a microphone, gyroscope, camera, accelerometer, and GPS receiver. Estrin et al. evocatively describe them as *"imager-microphone-wireless-sensor packages that we all carry on our belts and in our pockets"* (Estrin 2007, p. 3). Paulos suggests that we are witnessing a fundamental transformation of the mobile phone from a personal communication tool into a *"networked mobile personal measurement instrument"* (Paulos et al. 2009, p. 414). While in the western world there has certainly been an increase in the public visibility of smartphones as a desirable object, we suggest that there is a need to examine how evenly this technology is distributed, and to conduct ethnographic research on the actual everyday practices that are enabled by these devices.

11.1.1.2 The Environment is Measurable and Modular

Participatory sensing is premised on the collection of large data sets. The key concept is the notion of the data point, which through digital sampling transforms the continuous flow of the world into a set of discrete entries in a database. These entries share properties such as timestamps and spatial coordinates, which allow data points from different devices and users to be aggregated into a single dataset. Participatory sensing conceives of environmental sensing as a distributed digitisation task that can be reassembled as a dataset of the 'environment'. The assumption is that by collecting vast amounts of data, that ever more detailed and accurate representations of the environment can be produced. A metaphor might be an attempt to build high resolution maps of the world like Google Earth by organising every single human on earth to use their own flatbed scanner to digitise their surroundings. Would the resulting data create a meaningful representation of the environment? At the heart of participatory sensing is a belief that mass quantification is the primary way of gaining knowledge about the environment. Yet it is worth considering the limits of this method and questioning what other means of engaging with the environment might be sidelined by this approach.

11.1.1.3 Crowdsourcing Provides Free Labour and Technology

Participatory sensing typically uses the notion of crowdsourcing (Letts 2006) and micro-tasks. This involves breaking-down large scale problems into smaller modular tasks that can be outsourced to a large number of external workers. The idea is that participatory sensing can gather large amounts of distributed data beyond the few expensive sensor stations that are currently used for environmental monitoring. Thus running these projects becomes an organisational and managerial task of encouraging people to participate and making sure there is enough coverage to create continuous datasets. This outsourcing also extends to the sensor hardware itself. While smartphones possess powerful sensors, they are not autonomous and they require people to operate them and support them. Even sensing apps that run as background processes and do not require active input from the user, need people to charge the phone battery, pay the bills and make sure that things are functioning properly. Thus the benefit of participatory sensing is that the tricky tasks of power management, network formation and maintenance (Honicky 2011) are handed over to the phone's owner. From a researcher's perspective, crowdsourcing seems to offer enormous savings in terms of labour and hardware costs. The assumption is that it is possible to achieve a successful and stable division of labour with the researchers defining problems and creating technologies, while the participants carry out repetitive tasks using their own smartphones, exactly as instructed. Yet crowdsourcing does not acknowledge the range of costs and impacts associated with this model of sensing, in terms of participant and researcher labour and material practices.

11.1.1.4 People are Less Reliable than Technologies

Throughout the participatory sensing literature, participants are often described as **MULEs** (mobile ubiquitous LAN extensions) (Bhadauria et al. 2011; Ganti et al. 2008; Shah et al. 2003; Tseng et al. 2010; Wu et al. 2009; Yang et al. 2013). This term describes ‘platforms’ that provide mobility for technical sensors and allow them to cover larger areas. The term MULEs does not differentiate between animals, humans or moving machinery, since they can all transport sensors. In this vision, the assumption is that sensing is purely a technical activity ~~and it is not done by humans~~. The sensor is a piece of technical hardware that is separate from the MULE itself; see Fig. 11.1. In this vision, the role of the human is merely to act as a bipedal sensing platform that facilitates the sensor technology. In fact, participants are often seen as a point of failure that can inhibit the technical sensor by introducing inaccurate or malicious data (Yang et al. 2011). Wang et al. argue, that *“unlike well-calibrated and well-tested infrastructure sensors, humans are less reliable, and the likelihood that participants’ measurements are correct is often unknown a priori”* (Wang et al. 2011, p. 7). This approach to participatory sensing presupposes that the technological sensor is de-facto ‘correct’, while humans are unpredictable. In order to standardise the behaviour of participants, the literature

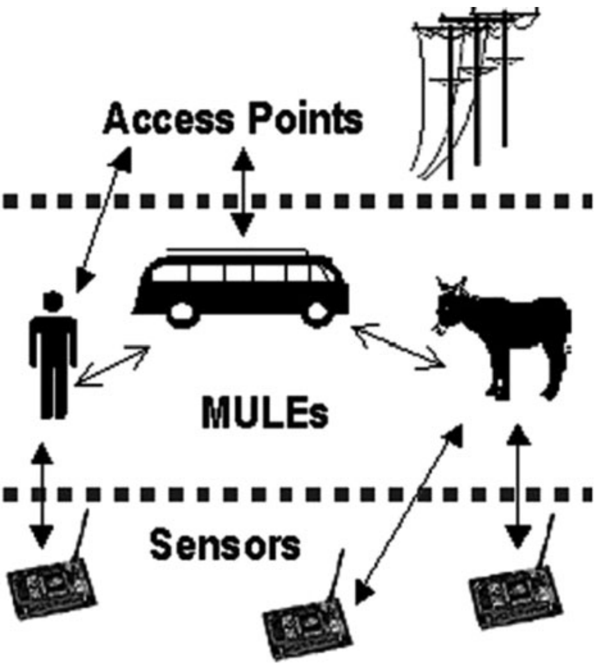

Fig. 11.1 Illustration from Shah et al. (2003) showing the notion of MULEs as human/animal/machine platforms that are distinct from the sensors themselves. Note the *dotted line* which visually separates MULEs from the sensors

suggests rigorous (Dickinson et al. 2010) and differential protocols, which, for example, allow skilled volunteers to count every bird, while less skilled ones are restricted to counting the most easily recognised (Cohn 2008). The assumption is that there is a single scientifically/technically correct way of gathering data about the environment that is embedded into technical protocols. This creates an apparent chasm between researchers' notions of data quality and the way in which participants are imagined to behave. In effect, participants are not involved in setting the agenda with regards to what or how the environment might be sensed. Our concern is that this approach to sensing excludes the ways in which humans experience and interact with the environment and it also dictates the kind of phenomena that can be sensed. The environment becomes defined as those phenomena that the researchers deem valuable and which the hardware sensor can measure. How does this sidelining of human capacities, such as recognising, interpreting and acting within physical and social contexts shape environmental sensing?

11.1.1.5 Motivation is a Universal Property

As we noted earlier, for practical reasons, crowdsourcing is reliant on people's participation. One of the key discussions within the participatory sensing and crowdsourcing literature is how to attract people and maintain their active participation (Massung et al. 2013). The literature summarises this problem via the notion of 'motivation', as a range of internal factors that are seen to dictate people's participation. One area of discourse uses behavioural psychology (Nov et al. 2011; Rotman et al. 2012) to identify essentialist drives that are categorised. The supposition is that motivation is a universal and identifiable property possessed by humans in the same way as their mass in kilograms. Another way in which motivation is conceived is by perceiving people as isolated and economically selfish individuals. There are many papers that propose a data market for participatory sensing, where users are paid for their data points as set by a commercial supply and demand market (Lan and Wang 2013; Luo and Tham 2012; Tham and Luo 2013). Thus 'motivation' becomes an economic model for operationalising users. What these approaches have in common is that they see motivation as an internal property of participants and not as external properties such as the attractiveness of a particular sensing task or process, the quality of the interface design of the sensing device or the recruitment work done by the researchers. What affect does this way of understanding motivation have on the success of trying to recruit participants?

11.1.1.6 Engagement Can Be Automated

Particular gaps within the participatory sensing literature that are worthy of note are the specific methods used to contact potential participants and the manner in which the sensing processes are managed throughout a project. Much of the literature assumes that sensing projects are inherently attractive and will propagate themselves via social media (Boulos et al. 2011) or automated recruitment mechanisms (Reddy et al. 2010). The hope is that projects will go ‘viral’ and reach a ‘tipping point’ (Srivastava et al. 1958), and thus will recruit large audiences of participants. There is some detail about how to recruit for online projects using ‘game-like contribution channels’, ‘network coordination services’ (Yang et al. 2013) and ‘micro-task markets’ (Kittur et al. 2008), but there is little detail about how to recruit for participatory sensing. We suggest that participatory sensing is inherently different from online crowdsourcing in that it requires participants to physically carry hardware and sensors whilst transversing outdoor areas. These activities involve learning about the maintenance of hardware sensors as well as requiring significant time commitments to execute the sensing processes themselves. Yet to our knowledge, there are few papers that explicitly address the specific requirements of recruiting participants for environmental sensing and we found only a small number that discuss recruitment methods (Amintoosi and Kanhere 2013; Reddy et al. 2010, 2009; Tuncay et al. 2013). These describe matchmaking systems that use databases of people and their devices to allow matching with the requirements of sensing campaigns. The databases contain details of the *“participants’ device capabilities, geographic and temporal availability, demographic diversity, and social network affiliation”* (Reddy et al. 2010, p.140). It is unclear how sensitive information about potential participants such as their mobile phone number, location and availability appear in theses databases. Presumably, for such a system to work, the overall project would have to be publicised and individuals contacted in order to gain their consent and to collect the data. Once a match is made with a potential participant they would have to be contacted by telephone or email in order to initiate the actual sensing activity itself. Yet the inter-personal practicalities of how this might be accomplished are not addressed in this literature, which instead focuses on the technical implementation of matchmaking algorithms. Two of the papers Tuncay et al. (2013) and Amintoosi and Kanhere (2013) go some way to offer technical solutions. They propose that once a match is made, a ‘recruiter node’ (Tuncay et al. 2013) will automatically ‘recruit’ another phone to join the sensing campaign. Yet how realistic are these ideas? The matchmaking proposals appear to be small scale experiments or conceptual models and scaling them up would increase the need to interact with people in order to determine their availability, hardware and location. It is hard to imagine that large numbers of people would volunteer their personal mobile phone for a project that would take remote control of their phone. To build a global recruitment system with large numbers of users would present a range of problems that are not addressed. We also question what kinds of sensing campaigns actually benefit from avoiding direct interactions between researchers and participants. Can automated recruitment create coherent sensing campaigns where the researchers understand what the participants are doing as they create data?

11.2 The WideNoise Case Study

How does participatory sensing actually function? In particular, how do sensing projects manage to recruit participants? In this section, we explore a case study and model for recruitment that highlights the role of the researcher as facilitator and actively engages participants in sensing. The case study is of a smartphone app called WideNoise (EveryAware 2012), which is free to download for iOS and Android operating systems. It allows users to take sound level measurements, which are geo-referenced using the inbuilt GPS and sent to a server where the data is mapped and displayed for participants and researchers. The app was created as part of the EveryAware project, which was funded under the European Seventh Framework Programme within the Information Communication Technologies theme. The EveryAware project aimed to combine a technological and participant focus in order to use environmental sensing for participant awareness enhancement and behavioural change. The project involved the development of new sensing devices as well as technological platforms for data-processing (EveryAware 2011), which were tested using practical deployments of sensors with participants. The project's focus was to demonstrate the utility of low cost sensors deployed as a large distributed network, the point being that the scale and granularity of 'formal' or 'official' environmental data gathering is currently limited due to the cost of sensors and the resources required for large scale data collection. Using low cost sensors operated by participants was intended to address this cost issue as well as achieving better temporal-spatial coverage than the existing sensor networks can provide. Within the EveryAware project, we were responsible for the 'recruitment and engagement of people'. This meant that our role was to identify ways to contact and enlist as many participants as possible, to execute the participatory sensing process and become data gatherers. This responsibility was assigned to us largely due to our previous experience in participatory projects as independent practitioners and members of the ExCiteS (Extreme Citizen Science) research group, whose work is centred on public participation in scientific research.

11.2.1 An Issue-Centred Approach to Recruitment and Campaign Creation

As we described in the introduction, the EveryAware project incorporates many of the assumptions of participatory sensing. In this section we would like to describe the pragmatic balancing act in which we negotiated the technology-centred assumptions, while setting up an issue-centred sensing project in collaboration with a local community group. We based our approach on a wide variety of literature that discusses participation both theoretically and as practical methods. Within participatory rural appraisal (Chambers 1994) a large body of literature suggests that the role of the researcher is that of a catalyst and facilitator of community research that is carried out by the groups themselves. Participatory action research (Reason and Torbert 2001) highlights the need to shorten the distance between research activity and real world change in order to promote social justice. This approach emphasises the need for the researcher's own personal emotional involvement in the research. Participatory design (Björgvinsson et al. 2012) focuses on collaborative design with collectives of people around matters of concern. Community mapping (Perkins 2007) and community art (de Bruyne and Gielen 2009) demonstrate the complexities of 'working with' and 'representing' communities. In our work as participatory practitioners over the past decade, we have used these ideas to sensitise ourselves to the dynamics of relationships with participants. Based on our experience with sensing projects such as Bio Mapping (Nold 2004), Urban Tapestries (Angus et al. 2008) and Feral Robotic Dogs (Jeremijenko 2002), engagement involves collaboration with local organisations and personal communication with individuals. This approach takes a considerable amount of time and requires flexibility and sensitivity on the part of the researchers/project initiators.

In the context of the EveryAware project, these approaches needed to be balanced with our role of recruiting people in order to generate a large amount of data using the WideNoise app. This pre-defined role precluded full collaboration, which would have involved co-designing a project from problem identification to the final design of a suitable sensing device. Within the project we found ourselves in a position in which we were trying to build a participatory process around a prefabricated device. To do this, we expanded on the work of D'Hondt et al. (2013), Chamberlain et al. (2013), who discuss the possibility of combining community processes with participatory sensing. We took a pragmatist position insofar as various kinds of participation were deemed possible within various contexts, as opposed to the binary approach of participation or no participation. Since we were dealing with a ready-made device, which would be deployed for public use, we had to investigate its capabilities. This involved analysing the technical aspects of the application in terms of the way in which sound level calculations were made as well as the details pertaining to the interface and end-user requirements. All of these aspects would have an impact on what would be achievable with the device in a participatory sensing process.

WideNoise was originally developed by a company to demonstrate the scalability of Internet of Things scenarios and not specifically as a tool for environmental sensing (WideTag 2012). For use within the EveryAware project some interface changes were made, including the introduction of sliders and text fields for 'subjective' data entry. In order to evaluate the accuracy of the application, we performed sound level tests in an anechoic chamber following the test procedure laid out by D'Hondt et al. (2013) to compare the level of accuracy with a calibrated Class 1 sound meter. The results showed that WideNoise produced highly variable results when running on different phone models and offered poor correlation to the reference meter. Furthermore, the app did not display readings in dB(A), but presented an unweighted decibel value. We concluded that any data generated by the app would not be directly comparable to official noise standards and could only provide a rough indication of sound pressure. WideNoise does not support continuous monitoring but is based on brief sound events that are actively and consciously chosen by the user. These features meant that the application had radically different characteristics to those of a traditional noise meter, which is designed to measure sound pressure over long durations and within a narrow and specified error margin. Taking the concept of MULEs into consideration and given the disparity between WideNoise and a class 1, or even class 2 sound meter, it would have been difficult to adopt this notion of participants as bipedal sensing platforms of a technically superior environmental sensor.

While it was obvious from the name choice and visual imagery used on the app's interface that WideNoise was designed to sense sound, its intended usage and protocol scenario were less clear. The application does not make any suggestions about what, where, when or how to measure sound. The interface provided a series of icons including a feather, a sleeping cat, a TV, a rock concert, a dragster and a T-rex. These icons symbolised sound volume rather than suggestions regarding what to measure. In the design of the application, particular attention was given to the aesthetics and user interface to make it quick and easy to take a sound level reading, geolocate it, and upload it to an online map. The interface interaction flow involves the user opening the application and pressing a button to take a sound measurement, which typically takes 5 s. During this sampling period, the user can drag a slider on the interface to guess the current sound level. Once the sound sample has been taken the level measured by the device is shown next to the user's estimate and the user is given feedback on the accuracy of their guess such as 'good!' or 'no match'. The user is then asked to add subjective descriptions using a number of interface sliders, ~~and~~ textual input via tags, and lastly, to submit the data to the server. The app has a predominant focus on the interface sliders used to rate and tag the sound, which is geared more towards content creation in a social media context as presented in concepts such as 'humans as sensors' (Forrest 2010), 'people as sensors' (Resch 2013) and 'social sensors' (Sakaki et al. 2009). The focus in these approaches is that the participants are creating data that is described as 'subjective' user observations (Fig. 11.2).

In order to understand the usability and usage context of the app, we trialled it with a dozen students and researchers for a number of weeks as well as with a larger group of researchers at a public event and asked them to comment on usability aspects and when or how they might use the app. Their feedback was that the application presented no specific purpose for, or context in which to take sound measurements. Yet on the positive side, the respondents said that the interface was easy-to-use. We hired an advertising company to help develop a marketing campaign in order to carry out a pilot project. Their comment with regard to trialling the app was, *"I sort of felt - is that it? It has gone off somewhere but I have no understanding what I have participated in"*. We concluded that the app by itself without any other contextual information presented the act of taking a noise measurement as an arbitrary and meaningless exercise. Based on the formal user feedback and a test campaign by the advertising company, we recognised that if we simply promoted the app on its own it would be extremely difficult to recruit large numbers of people to use the application over a sustained period of time.

WideNoise has unique properties that make it very different from a traditional environmental noise monitor. In order to recruit people, we took into account these

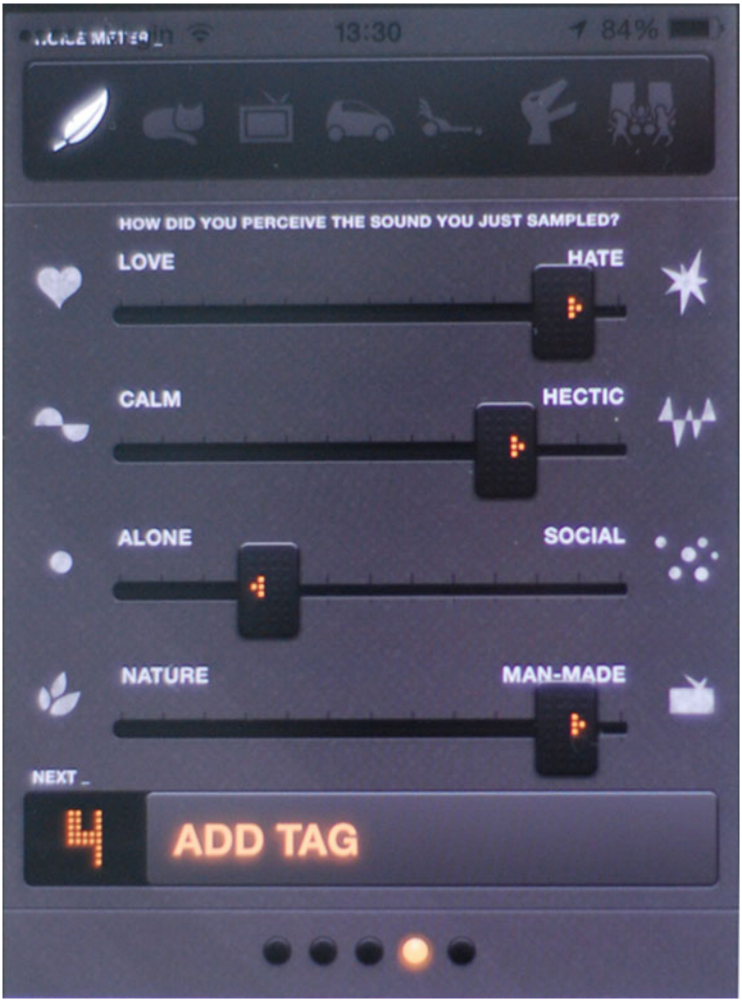

Fig. 11.2 WideNoise interface sliders that allow user to rate the sound measurement they have just created

properties and tried to intertwine them into a narrative that we could communicate to potential participants. We went through a period of brainstorming and design in order to create a sensing process that would encase WideNoise within a broader conceptual framework in which individual sound recordings would contribute towards a larger purpose. We tried to construct a reason for participants to take measurements—something that would make a sound measurement worthwhile and that would make sense of the numerical decibel data. Rather than framing sound simply as a measurable property of the environment, we focused on sound as having an explicit source. This shifted the concept of the environment away from abstract data towards the dynamic interactions between humans and non-humans. In this approach, sound has a 'source', which people can be affected by. It becomes more than sound pressure; it becomes noise and an issue and has an emotional dimension as well as a decibel value. We hypothesised that in this way sound might function as something that people gather around. By framing WideNoise as an issue, we felt that it would be easier to recruit people who were already affected by sound. We considered a number of potential contexts, including neighbour noise nuisance, wind farms or aircraft noise. We chose the issue of aircraft noise around Heathrow Airport in London as the context for our pilot, since it was a broad and public issue that we could use to assemble a collective of people. The airport is an emotive and political issue for local people, which we hoped would enable us to gather a group of engaged citizens for our sensing campaign. It is worth pausing at this stage to acknowledge that by choosing this context we effectively defined what the WideNoise app would be sensing. While we did not dictate or suggest that people should monitor airplane noise, targeting that specific area of London with an application capable of measuring sound invariably led to a major focus on aircraft noise. We let the design of the app and the requirements of the EveryAware project direct us to a context where sound would have meaning for a collective of potential users.

In line with the literature on participatory research, we created the campaign by identifying a local organisation and elected to work with ~~HACAN~~ (HACAN 2016), the largest voluntary organisation in Europe campaigning on behalf of people suffering from aircraft noise. We felt that collaborating with HACAN would afford the project greater legitimacy in terms of the noise issue and would attract more participants to the project. It was our view that it would be easier for us to try and attach WideNoise onto an existing issue and an organisation that already had a collective of people gathered around it. There would also be more potential for the project to have a positive impact on the noise issue if we partnered with HACAN. From HACAN's perspective, collaboration with an EU research project created legitimacy and publicity for the impact of noise on the Heathrow area. In terms of recruitment, HACAN supported the project by using their mailing list to circulate details of the project throughout their network. We also managed to raise external funding in order to employ a community officer, who was selected by the chairman of HACAN. This individual had local insider knowledge of the noise issue due to living close to the Heathrow runway and his role was to organise the project with local people. With the community officer we created a campaign, assigned it the name; 'Isleworth ~~Heathrow~~ Noise Map', and used the HACAN mailing list to invite their members to attend a series of workshops in the Heathrow area.

Workshops are a common participatory method for physically gathering people together for a short period of time. Workshops tend to be hosted in a local public space, often in a municipal building. They do not have any explicit format but tend to be informal gatherings. Usually people are expected to come together for a period of time to listen and then asked to actively contribute with questions and discussion; sometimes workshops involve organised activities. We created custom poster artwork and leaflets to promote the project and invited people to

Fig. 11.3 Poster design for the Isleworth Noise Map campaign. Sound is represented expressively as noise waves emanating from a plane flying overhead

the workshops; see Fig. 11.3. The posters were placed in local shops and other key locations throughout the target area. In addition, we wrote and designed a

WideNoise manual that explained how to measure sound using the app and the online noise mapping system that could show personal as well as communal noise exposure. We managed to get mainstream televised news coverage for the campaign as well as radio, print and online newspaper coverage. The launch of the 'Isleworth Noise Map' was attended by the chairman of HACAN and a local politician as well as 40 local people. We explained the wider project of building a collaborative noise map and proceeded to help people install the WideNoise app on their phones. We taught people how to use the application and answered their questions. After this initial workshop we hosted another two local workshops. The project community officer kept in close contact with the participants who had the software installed on their phones and arranged local meetings where he could solve people's technical problems with the app and phone. We also continued the communication campaign with additional mailings and interviews on local radio stations as well as in newspapers. As a result of the campaign the project was adopted by a local council who organised workshops and publicised the project. The council felt that the project was so successful that they used the WideNoise data generated by local residents as the basis for their official response to an important UK governmental commission to make proposals on future airport expansion.

11.3 Reconsidering the Assumptions of Participatory Sensing

In the following section we use the case study to reflect back and examine the ways in which some of the assumptions of participatory sensing played out in practice. We go on to explore whether the case study itself suggests some way of going beyond these assumptions.

11.3.1 Everybody Has a Smartphone

During the face-to-face workshops, it was apparent that most of the local people who wanted to take part in noise monitoring were retired and few had suitable modern smartphones. Amongst those that owned a smartphone, few had ever downloaded an app before. Therefore, in order to make the project possible, we had to purchase twenty new smartphones with pre-paid sim cards and lend them to the participants for the duration of the project. We also had to train people in how to use the Android interface as well as the WideNoise app itself. We found that there were significant interface issues related to the user registration, which made it very difficult to use the application. While people were highly motivated to participate, the challenge of using the app was restrictive. In the participatory sensing literature, there is virtually no discussion about the impact of good or bad interface design or the demographic makeup of the intended users. The emphasis on smartphone penetration within the literature obscures the fact that the world is not solely composed of people with the newest and most expensive smartphones; nor are they uniform in their technical aptitude. This raises questions about the central assumption of participatory sensing, which hinges on the ubiquity and accessibility of smartphones. We question the implicit assumption that only rich and technologically literate people should be able to sense the environment. By making a modern smartphone a prerequisite for environmental sensing, large numbers of potential participants are effectively excluded—precisely those people who are most likely to be affected by pollution and blighted by poor local environments.

11.3.2 The Environment is Measurable and Modular

The case study demonstrates that measuring noise pollution with a smartphone application can garner lots of publicity and attract large numbers of people. Yet this campaign was carried out within the context of a very specific issue where measuring noise became a useful and meaningful exercise for people affected by a particular problem. By taking part in the project they were not simply trying to create large quantities of data for scientific research. Based on our surveys and interviews, the participants conveyed the fact that they were trying to attract public and media attention and create political pressure on representatives, whilst also creating evidence of personal exposure and strength of feeling. While this did not necessarily mean that they were not interested in generating scientific data this was not their main objective. This created some problems for the project, the objective of which was to obtain large numbers of measurements, across multiple grid squares, throughout the day and night in order to collect sufficient temporal and spatial coverage to create noise maps. This was not of particular interest to the participants, whose focus was on the pollution exposure caused by the planes flying directly above their heads. This meant that most of the measurements were taken in people's immediate surroundings, often in their gardens or within their houses, rather than across the expanse of the grid squares. Since they were trying to measure the planes themselves, they were measuring peak noise measurements when an aircraft was overhead. In meetings, the participants started to develop and share their own protocols and notions of rigour, which differed from those of the EveryAware research team. During one workshop discussion, one participant said, *"I think for the future it would be much more important to have the rigour, and the rigour should say first of all we will not average readings. And secondly, there should be an encouragement for people not to record less than 75, or 70 or whatever it is. Because to influence the people to whom this applies, it seems to me they are not interested in the fact we have taken 5000 readings and the average is 76. What's going to influence them is that 10 % of the readings were above 85 or whatever and if we cut out all the smaller readings the data that they will get will get bigger and bigger and bigger"*. The participant argued that special rigour was required to capture the peak noise during the overflight of an aeroplane, and that this was more important than averaging readings, since it would create more political impact and increase the growth of the project and the wider political issue. What emerges from this comment is an alternative conception of how and why to carry out empirical measurements. It also clarifies the fact that the project's protocols for collecting data across multiple grid squares is only one of many possible empirical protocols. We argue that this approach of focusing on peak aircraft noise was also a clear result of the short measuring period allowed within the WideNoise application design. The participants appropriated the affordances of the application in conjunction with their own agenda, in order to use the device in such a way that it made sense of taking noise measurements within the Heathrow context. This case study thus challenges the assumption of participatory sensing, in that data gathering will invariably follow the scientist's notion of how to construct rigorous protocols. A successful participatory sensing project requires a collaboration between researchers, local groups and individuals on developing appropriate protocols and devices that mutually support the goals of the involved parties and their different epistemologies.

11.3.3 Crowdsourcing Provides Free Labour and Technology

The participatory sensing literature assumes that it is easy to crowdsource free labour and technology. In contrast, we would like to describe some of the intricate work involved in preparing the smartphones that were lent to the case study participants. We set out to buy twenty identical smartphones but due to 'security concerns' in UK shops it is only possible to buy a few phones in a single purchase. This meant that in order to buy all of the phones we had to go to multiple shops, which resulted in the phones being registered to a number of different telecom providers. Since we did not want to purchase contracts for these phones, we had to buy top-up vouchers for each phone and for the different network providers. Unpacking each phone from its plastic casing, charging the batteries, and setting it up with a unique SIM card and adding credit took a significant amount of time. We then had to go through the phone system settings to remove extraneous interface elements and set up all of the necessary internet access parameters, which required multiple SMS exchanges with each service provider. We then had to download and install the WideNoise app onto each phone. On the Android platform this requires a valid Google account in order to access the Google Play appstore. This meant that we either had to create a separate account for each phone or use a single account on all of the phones. For simplicity, we opted to use a single account to sign into all of the phones. This skewed the registration data for the number of unique user application downloads. Setting up WideNoise also required a separate registration process with an email address, which also needed to be confirmed. Unfortunately some of the phones did not function properly and had to be replaced and switched amongst the participants. This meant that we ended up with a certain number of registration mismatches between users, user accounts, and phone hardware. These multiple levels of registrations, logins, account details and credit levels made it very challenging to administer the project and keep track of the data produced by individual users and devices. The emphasis here is that in this case study the smartphone technology did not save on labour for either the researchers or the participants. Smartphones are not stand alone pieces of computing hardware. In fact, these devices only function as part of complex commercial, technical and legal networks comprising telecoms companies, hardware manufacturers, software platforms and government legislation. The use of smartphones as the basic unit of research means having to deal with the vagaries of the telecoms industry. One of the main problems we identified was the socio-technical assumption that each phone is owned by a single user and that the person setting up the device will also be the end user. This end user is required to enter lots of personal information in order to set up and initiate the device and the application. To our knowledge, there is currently no administrative system within participatory sensing that would allow for a centralised setup and ongoing management of a diverse collection of phones and apps by a project coordinator. This makes it very difficult to use smartphones for collective purposes. Rather than saving time or money, the use of smartphones in crowdsourcing projects involves large amounts of hidden labour and costs that are generally unacknowledged.

11.3.4 People Are Less Reliable Than technologies

The case study calls into question the assumption that technologies are invariably accurate. Despite having to use a highly inaccurate and untrustworthy technology, the case study demonstrated the role that participants can play in appropriating sensing for their own goals and agendas. This challenges the characterisation of people as MULEs, which elevates the technology, in this case the sensor, and excludes human decision-making. Unfortunately, in the literature, we still see a considerable degree of concern about the quality of participant observations and the associated dangers of *"wilful falsification, human deceipt[sic] and data manipulation"* (Srivastava et al. 1958, p. 189). Yet in environmental sensing projects, the participants who are involved are often living next to the source of the pollution and are directly affected by it. This means that they have acquired a breadth of expertise that makes them specific kinds of experts on that situation (Wynne 1992). In contrast, this highly specific expertise is often not available to the researchers, who are only looking at data. In the Heathrow case study, we observed that many of the participants were vastly more knowledgeable about the technical and legislative aspects of noise than our research team. We feel that it is dangerous to treat researchers and technologies as infallible, while participants are treated as unreliable sensors or MULEs. For participatory sensing to progress, it will have to acknowledge that there are different types of expertise that need to be brought together, not just a single one that can be embedded into technological sensors.

11.3.5 Motivation is a Universal Property

Why did people take part in the Heathrow project? The answer is that the project offered the participants a way in which to deal with local noise issues that were directly affecting them. In the pre-project survey, the participants wrote that they wanted to *"raise the bar for politicians thinking about the 3rd runway"*, and demonstrate the emotional impact of noise by bringing *"greater recognition of the impact of noise especially the frequency of interruption by planes"*. In this case study, motivation emerges not as internal, psychological or abstract, but as something that is involved with the external world; it is specific and contextual. For the participants, their motivation to take part in the sensing was intrinsically linked to the personal, communal and local relevance of noise. Thus in this case, the ability to sense aeroplane noise was critical since it functioned as a lynchpin in terms of political decisions about the future expansion of Heathrow airport, which would have a direct negative impact on their future quality of life. These clearly articulated and material motivations challenge the way in which crowdsourcing envisages motivation as abstract and universal. How would the practices of participatory sensing change if it actively engaged with people's real-world motivations rather than postulating essentialist drives?

11.3.6 Engagement Can Be Automated

As outlined earlier, very little has been written about recruitment for participatory sensing. The methods suggested for automated recruitment do not appear to offer viable solutions en masse. We suggest that this case study has demonstrated the viability of an issue-centred approach. By organising a series of workshops in the local area, we had many opportunities to communicate directly with the participants and crucially, the participants had opportunities to meet each other. This meant that the project did not only involve data collection; it created a collective effort of mapping noise. In addition, our proximity allowed fortuitous encounters to take place, which would not have been possible using an automated recruitment method. During one of our visits, we stopped at a local restaurant next to the workshop venue. After discussing the project with the owner, he decided to attend the workshop and he ended up participating and collecting data over a number of weeks. Our close contact with the participants also meant that we could support them by answering their questions about the software and replacing broken smartphones. We grew to understand how they were collecting data and what they were aiming to do with their collected data. This allowed us to create a number of custom noise visualisations, which focused ~~only~~ on the local impact of the airport. As a result of our issue-centred campaign, 80 people attended the face-to-face workshops as well as lots of public media and we managed to make the resulting data valuable for democratic decision-making on airport policy. Using this approach, 252 people (unique devices)

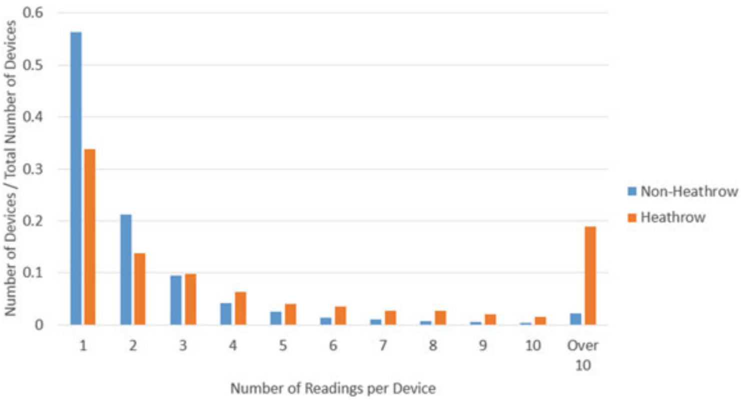

Fig. 11.4 Graph comparing the number of readings created per device in Heathrow vs. the rest of the world. 19 % of users in Heathrow took more than 10 readings while only 2 % in the rest of the world

took part in creating sound measurements around Heathrow and 6666 data points were generated in the area. We can compare the data from the focused sensing campaign with data from the rest of the world where people have downloaded the app independently, for their own purposes; see Fig. 11.4. The Heathrow data suggests that people on average took many measurements over an extended period of time, while in the rest of the world only 2 % have created more than ten data points. This suggests that using the app in an issue-centred context creates more in-depth and long term engagement, which makes sensing a valuable rather than an arbitrary process. These results suggest that an issue-centred approach to sensing can work for the benefit of local participants and local institutions as well as researchers. We argue that issue-centred approaches need to be seen as a viable model for participatory sensing projects.

11.4 Conclusions

This paper has described a number of assumptions of participatory sensing and the ways in which they create points of tension for the practice of sensing. We examined a case study that used the WideNoise app within the framework of an EU research project and described the technical and user testing required to understand the capabilities and constraints of the app. Based on the specific properties of the device, we outline an issue-centred approach to encase the app within a local issue of concern in order to recruit participants. Finally, the case study reflects on the assumptions of participatory sensing, the way they materialised within the case study and how we might be able to move beyond them.

Our key observation throughout this paper is the importance of the smartphone and its affordances, as well as the specifics of the software choices made in the design of the WideNoise app. The qualities of the device opened up and closed down many of the possible directions for a participatory sensing campaign. Our argument is not that technology fully determines sensing and that practitioners simply have to adjust to them. In a more nuanced way, we suggest that the technical and conceptual limitations of the hardware and application actively created possibilities as well as boundaries. We would like to describe our approach to participation and sensing as 'pragmatist' and in a tradition from Dewey (1927). This suggests a pragmatic approach to truth gained through pluralistic methods where facts and values are interlaced (Barnett and Bridge 2013; Hepple 2008) and brought together through experimental practices (Marres 2007). A pragmatist approach to participatory sensing means engaging with the real- world constraints of hardware, software and organisational requirements and trying to make the best of what one has within a real-world context. Thus, a pragmatist approach is honest in examining and communicating the limitations and trying to work with them to create a project. While in general it is better to be able to build custom applications and hardware for a specific social and issue context this is not always possible. At the same time, pragmatism also means a lack of idealism about the human aspects of sensing in terms of people's supposed motivations. A pragmatic approach to participatory sensing is one of design based problem-solving. By using the word 'design', we propose that the device is not finished when a smartphone leaves the assembly line, or when a software developer has submitted the final update to the app store. Design carries on into the setting up of the sensing campaign. In our role as participation practitioners in this case study, we were redesigning the implementation of the WideNoise application. Furthermore, the users themselves were carrying out a type of design work in the way in which they created their own protocols of when and how to take measurements. If we adopt this expanded notion of design, then participatory sensing becomes much more nuanced in terms of the roles that researchers, participants, technologies and issues play. We would like to propose that in participatory sensing, humans and technology come together around issues of concern to form sensing assemblages. This idea of an assemblage meaning literally a collection of things, describes this movement of gathering together that occurs within sensing. This idea of a gathering is a challenge to the assumptions of participatory sensing, which usually treats technologies and participants as entirely separate. By starting to draw this assemblage around an issue at the centre of our approach, we are in fact reframing problems such as motivation and recruitment as starting points and not merely something to be added to a technology. If participatory sensing aims to be truly participatory, then it will have to fundamentally rethink the design and development of its software and hardware platforms. Sensing assemblages need to be designed to support specific use-cases. Academic research processes need to be flexible enough to pragmatically adapt to the specific contexts in which the device is used and should be able to incorporate feedback and suggestions from participants in an iterative design process. Engaging with issues and working with participants needs to become part of the core design of creating sensing assemblages. Unless participatory sensing addresses the assumptions that become embedded into the design of its software, hardware and telecoms ecology, it will not be able to achieve its full potential. Participatory sensing can elect to construct the environment as a flat cartesian surface of data points without dynamics and life, or it can actively engage with the range of entities that are producing vibration or are at the receiving end of vibration. Using an issue-centred and pragmatic approach gives sensing an expanded context in which it can progress beyond recruiting data drones, towards engaging with the mechanisms and dynamics that cause environmental pollution. In this way we can build a future of participatory sensing that allows humans and machines to equitably co-sense the environment together.

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