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Experimenting with the Social Life of Homes: Sensor Governmentality and Its Frictions

Martín Tironi and Matías Valderrama

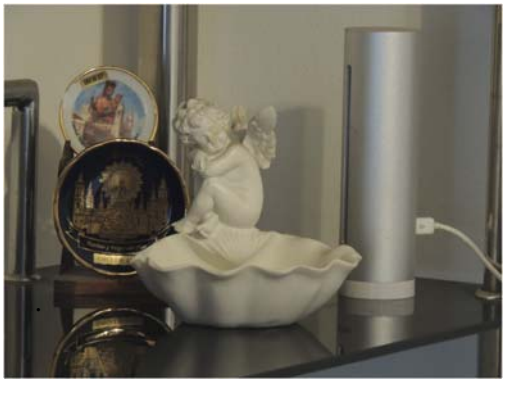
School of Design, Pontificia Universidad Católica de Chile, Santiago, Chile

ABSTRACT

Smart devices are invading everyday spaces like our bedrooms and living rooms, making it possible to conduct new participatory experimentations in the 'real world'. An example is the National Housing Monitoring Network (Red Nacional de Monitoreo, ReNaM). By installing networked sensors in homes in different cities in Chile, ReNaM seeks to generate a large public database on the environmental behaviour of homes in real life conditions and throughout their life cycle, in order to make data-driven policies and regulations on sustainable building. In this article, we argue that experiments with digital innovations like ReNaM are moving towards a 'sensor governmentality' or a mode of sensitive regulation of household behaviour at a distance, recomposing the relationship that the State establishes with its population. However, we find that this sensor governmentality is multivalent, fragile and friction-loaded. We analyse different scripts present in ReNaM and the frictions that emerge between divergent ways of materialising this sensor network from above and below. Moreover, the real environmental conditions and behaviours that the experiment seeks to capture through sensors are always challenged by the multiple entanglements that sensor devices unfold in domestic spaces, suggesting that affective and collective possibilities in these real-world experiments should be considered.

KEYWORDS

Real-world experiment; data-driven decisions; citizen sensing; domestic appropriation; speculative sensing



CONTACT Martín Tironi martin.tironi@uc.cl

> The dining room had an opaque glass shelf with metal pillars. There was the 'data gatherer,' as Claudio called it. The State sensor stood among family photos of babies and a grandmother, wedding and cathedral souvenirs, a pair of candlesticks and a collection of small figurines of angelic children. It was a grey tower that stood among domestic and family objects so that it could silently quantify and transmit data on the environmental behaviour of the home.
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> Extract from Field Notes, 25 February 2019

Introduction

The 'data gatherer' in the photo is one of the more than of 300 sensor devices installed in different Chilean cities by the National Housing Monitoring Network (*Red Nacional de Monitoreo*, ReNaM). This unprecedented public experiment was launched in 2014 by Chile's Ministry of Housing and Urban Development (*Ministerio de Vivienda y Urbanismo,* MINVU). Its purpose is to quantify and evaluate the quality or health of homes by installing sensors that measure environmental variables like temperature or noise levels. Public authorities chose to use a participatory approach to create a large public database on the real-life conditions of homes throughout their entire life cycle in order to make data-driven policies and regulations on sustainable building.

This experimental intervention is an example of how the State is introducing itself into the domestic spaces of homes through participatory digital innovation. In recent years, new networked infrastructures have been introduced in urban spaces under 'Smart Cities' projects around the world. These technology-driven projects usually follow a logic that by collecting real-time data on urban variables it will be possible to modernise governance and decision-making processes and achieve more efficient and sustainable cities (Kitchin, 2014; Gabrys, 2016; Tironi and Valderrama, 2018).

This smart logic is invading domestic spaces through technological trends like home automation and the Internet of Things. To be sure, media technologies have become an important part of contemporary domestic life (Church *et al.*, 2010). But if the domestic space has been conceived as a place of use and consumption of technologies such as microwaves, computers or televisions (Silverstone and Hirsch, 1994), now we see the inclusion of digital technologies oriented towards the quantification and monitoring of domestic life. Smart locks, lighting, metres, cameras and refrigerators, among many other devices, promise to make homes smarter by automating a number of household tasks and generating data on the thermal performance, purchasing preferences or energy consumption of each household (see Strengers, 2013; Maalsen and Sadowski, 2019).

These data have become very important for governments, which have a special interest in using smart devices to monitor homes, learn more about the behaviour of their inhabitants and create more data-driven policies and

regulations. Through digital innovations, State entities are appropriating experimental and participatory formats as innovative alternatives for changing institutional images and designing public policies (Laurent, 2017). Experiments outside of the lab allow for more participative and real-world interventions that provide insight into situations that are part of people's daily lives. These experiments in living (Marres, 2012), in which ordinary life becomes an object of intervention, gather data from the real world for various actors and agendas, redefining the relationship between science, policies and publics (Lezaun *et al.*, 2017).

Based on the new capabilities offered by digital innovations, several experiments are being carried out to test new modes of knowing and acting upon environments and individuals. In this sense, the case of ReNaM illustrates the changing relationships between experiments, participation and public policies with digital devices. Building on the ReNaM case-study, we seek to understand the interests that are put into play when efforts are made to turn cities or an entire country into a field of experimentation. Specifically, in this article, we explore two main questions: (1) What forms of knowledge and power become operable through participatory and real-world experiments with digital sensors? (2) How do users live with these sensors, confronting (or not) these new practices of knowing and governing through sensors? We examine how the lively and multi-layered ecology of homes, with all of the related feelings and cultural meanings of belonging and intimacy, is shaped and disrupted by this experiment with digital sensors. Through this two-fold inquiry, we critically interrogate how the supposed real behaviours and environmental conditions under study are always affected and disputed in this kind of real-world experiment.

Drawing on contributions from Governmentality Studies and Science and Technology Studies, we argue that experiments like ReNaM are moving towards a 'sensor governmentality'. Instead of relying on what people declare about their home environments, this sensor governmentality provides participatory and realistic knowledge based on continuous and recursive feedback from sensors installed in mundane spaces like the ReNaM's homes. Analysing this case, we show that unprecedented techniques and strategies are established in the Chilean State to make economically calculable and governable the real environmental conduct of households and their inhabitants, establishing normative criteria on what an optimal or sustainable habitat implies and ways to silently intervene in it.

However, we find that the environmental regulation of ReNaM households is an ambivalent, fragile and friction-loaded process. Different ideas of what ReNaM can and should achieve are put to test. We propose to analyse them under what the sociologist of science Madeleine Akrich (1992) defines as 'scripts'. These refer to the several intentions, values and ways in which users are expected to engage in their daily lives with artefacts such as the ReNaM's

sensors. As we will show, three scripts from above meet in the experiment not without certain frictions between state, scientific and participatory goals.

As an analytical term taken from physics, friction occurs when two or more bodies or actors and their aims diverge in awkward and unstable encounters. In her ethnographic account of global capitalism, the American anthropologist Anna Tsing states: 'Rubbing two sticks together produces heat and light; one stick alone is just a stick. As a metaphorical image, friction reminds us that heterogeneous and unequal encounters can lead to new arrangements of culture and power' (2005, p. 5). It is precisely these frictions, which are constantly tried to be hidden, that make it possible to set things in motion. Inspired by Tsing's conceptualisation of friction, rather than thinking about a form of friction-free governmentality, we need to make a symmetrical analysis of the frictions in both developers of the experiment and in the subjects under study. For that purpose, along the official scripts, we also examine the daily coexistence of ReNaM environmental sensors and the homes' inhabitants, evoking multiple motivations, uses and ways of making sense of the data gathered for their domestic purposes. We therefore also look at how this experiment is experienced from below in unique ways, opening up to unanticipated formats that go beyond the smart logic of problem-solving through data.

Approaching ReNaM from above and below will reveal the multivalence (Marres, 2012) of this sensor network or how it materialises multiple and divergent experimental arrangements that exceed the type of participation and knowledge that the State seeks to produce. Moreover, the idea of real environmental conditions and behaviours that the experiment seeks to capture through sensors is always challenged by the multiple entanglements that these devices unfold in domestic spaces. This implies for studies of smart living not trying to reduce these awkward encounters, but to be open to unexpected forms of engagement and speculate more affective and collective possibilities in these real-world experiments.

In the next section, we review the discussion on participatory and real-world experiments with digital sensors, and introduce the notion of sensor governmentality as an analytical lens for its understanding. In the empirical sections, we describe the development of ReNaM, the scripts identified and the different motivations and experiences of ReNaM users. We then offer some conclusions about this type of governmentality and problematise the definitions of participation that are drawn in this type of experiment in the real world.

Analytical Perspectives

Problematizing Participatory Sensing in Real-World Experiment

Digital innovations are changing the way we conduct experiments, collect data and analyse environmental phenomena such as temperature, noise or pollution

(Snyder *et al.*, 2013; Chapman *et al.*, 2017). As sensors become smaller and cheaper, it becomes possible to monitor the behaviour of humans and non-humans, but also a variety of environments. This opens up distributive forms of sensitivity, modifying how environments and their inhabitants are governed (Gabrys, 2016). As such, if the conditions of experimentation were traditionally limited to laboratories and research centres with expensive and complex technological instruments, they are now expanding to various spaces, permeating almost every area of contemporary life (Gross, 2016).

This expansion of experimental formats and methods promises to generate knowledge and testing *in vivo* or in the real world (Callon *et al.*, 2009; Evans and Karvonen, 2011; Marres, 2012; Gromme, 2015; Evans *et al.*, 2016; Gross, 2016; Tironi, 2020). Test beds, urban labs and real-world laboratories are becoming common initiatives for testing new technologies, policies or urban plans, among many others. In these experiments, innovations are not tested in a separate space prior to being embedded within society. Instead, they are introduced into everyday life to evaluate risks and demonstrate their capacities, reducing the distance between projection and actual use (Pinch, 1993; Tironi, 2020). Furthermore, *in vivo* experiments emphasise on testing hypotheses and learning from multiple relationships and practices of the real world, adapting to the uncertainty and messiness that reality implies (Evans and Karvonen, 2011; Evans *et al.*, 2016; Sengers *et al.*, 2016). As such, lively environments from homes to cities can be constituted as objects of calculation and intervention for testing the legitimacy or credibility of specific knowledge claims and promote certain futures instead of others.

Along with the capacities to experiment with real life conditions, digital innovations promise to expand forms of participation on public issues like global warming and environmental sustainability to everyday or mundane settings like our homes (Marres, 2012; Tironi, 2020). Of course, the participatory turn has been present in science, technology and innovation for a long time (see Delvenne and Macq, 2020), but digital devices have recently emerged as new means to make data collection processes more horizontal and participative. Open-source and DIY tools, platforms and civic apps can promote citizen participation and democratisation of environmental data (Boulos *et al.*, 2011; Gabrys, 2016; Powell, 2018). Beyond the traditional experts or formal institutions, it has been suggested that lay persons, amateurs and those affected by an issue can become sensors of their own city and gather relevant data to make public environmental problems and defend their demands (Goodchild, 2007; Boulos *et al.* 2011; Snyder *et al.*, 2013; Muller *et al.*, 2015).

However, the value of these participatory and real-world experiments has been problematised concerning the precision and quality of the collected data. Despite this, it has been argued that these participatory sensing initiatives would not seek to replace administrative or formal sources of

environmental data. On the contrary, non-traditional sensor network can serve as a useful and inexpensive way to access complementary data on coverage, quantity and spatial–temporal resolution, especially in countries with low environmental monitoring development (Boulos *et al.*, 2011; Snyder *et al.*, 2013; Muller *et al.*, 2015; Jiang *et al.*, 2016; Chapman *et al.*, 2017; Meier *et al.*, 2017).

Within this debate, Science and Technology Studies based on Actor-Network Theory or feminist approaches have suggested that the value of citizen sensing initiatives lies in the alternative practices to collect, analyse and communicate environmental data, reconfiguring the ways in which subjects can participate and get involved in their environments (see Gabrys, 2016; Marres, 2017). First, citizen sensing initiatives can generate new ways of being sensitive to environmental problems, including affective and sensorial aspects with data beyond numbers (Pritchard and Gabrys, 2016; Calvillo, 2018; Calvillo and Garnett, 2019). Second, scholars have emphasised the collective potential of citizen monitoring practices. These can lead, for example, to a commitment to air as an 'atmospheric commons' that affects to not just individuals, but whole communities and environments (Pritchard and Gabrys, 2016). Therefore, from these perspectives, citizen sensing should not focus on absolute numerical precision, but rather on achieving 'just good enough' data practices to generate affective and collective encounters to mobilise demands and improve planetary health (Gabrys *et al.*, 2016).

Governmentality by Sensors

Along with the question of what knowledge is generated in these real-world and participatory experiments through digital innovations, it is necessary to ask which forms of power become actionable through them. We must question how the smart logic extends to governments under the rhetoric of allowing for new forms of governance based on the supposed neutrality of sensors, algorithms and data. We thus propose to analyse environmental sensing operations such as ReNaM from the perspective of Governmentality Studies initiated by Michel Foucault (2007, 2008, see also Miller and Rose, 1990), which has more recently been expanded to understand digital technologies (Rouvroy and Berns, 2013; Gabrys, 2016; Introna, 2016).

Foucault (2007) defined governmentality as an ensemble formed by institutions, discourses, technologies, knowledge and techniques that make possible the exercise of a form of power whose main target is the population. Unlike disciplinary power, which seeks to normalise and reform bodies individually or in detail through artificial confinement, governmentality would seek to remotely regulate or conduct the conducts of the governed from a population perspective. Based on (neo)liberal rationality, governmentality does not seek detention but rather promotes the natural circulation of entities such as people, diseases,

animals, air, rivers or symbols, but within a medium (*milieu*) conditioned for it. The dangers and failures will be regulated and progressively annulled within a 'multivalent and transformable framework.' (Foucault, 2007, p. 20) It does so by circumscribing and calculating and economising the series of events of reality within favourable, positive or optimal probabilities and limits, identifying curves of normality from which the norms are derived. In other words, governmentality regulate reality through the possibilities and freedoms of the governed.

In *The Birth of Biopolitics,* Foucault outlines the concept of 'environnementalité' (environmentality), which is reworked by Jennifer Gabrys (2016) in her critique of Smart Cities. Gabrys emphasises modes of governance that are 'less oriented toward control over populations and instead performs through environmental modes of governance' (Gabrys, 2016, p. 192). This governance accentuates the way in which the conditions of environments can be programmed by digital means to implement forms of regulation without the actors even realising it, favouring certain ways of life over others. Whether in Smart City (Gabrys, 2016) or Smart Home initiatives (Maalsen and Sadowski, 2019), we can see how this regulatory power is implemented at a distance through digital innovations. Networked sensors inside the home or within urban infrastructure make it possible to quantify and calculate environments and entities in circulation in order to translate them into discrete and manageable magnitudes, aiming to achieve a more efficient and sustainable government.

The lens of governmentality allows us to situate the expansion of participatory and real-world experiments within long-standing power relations between forms of government and populations. In invoking the notion of sensor governmentality we seek to emphasise the emerging forms of knowledge and power that are enabled by the proliferation of sensing practices and infrastructures in society (Andrejevic and Burdon, 2015; Tironi & Sanchez-Criado, 2015; Gabrys, 2019; Klimburg-Witjes, Poechhacker and Bowker, 2020). Analysing the case of ReNaM from this perspective means looking at the sensorification of homes as way to translate the life of homes into measurable series of events, calculate their efficiency, sustainability or healthiness and act upon the conduct of new entities at a distance. Domestic sensors are devised for rendering the behaviour or conduct of homes as such, allowing to estimate, for example, whether a home behaves better than another. This conduct of homes would no longer be random, but would be sensitive to changes in their construction materials, climate and geographic conditions, or the habits of their inhabitants. In other words, the ReNaM sensors do not register pre-existing realities, but rather make a specific regime of quantification for household government exist in which practices and technologies, environments and policies, discourses and materialities become entangled. While the domestic space has remained relatively distant from the jurisdiction of the State

government, unsuspected forms of knowledge and public policy are opened up through the silent intrusion of sensor technologies like in ReNaM.

Methodological Approach

To fully describe and understand ReNaM, we conducted a case study between July 2018 and December 2019 that included in-depth interviews with eight key stakeholders involved in the development of ReNaM, thirteen home visits with users and the analysis of secondary materials.

Five interviews were conducted with current members of MINVU and former officials who participated in the genesis of the project. Four interviews were conducted with people who have participated as counterparts in the development of ReNaM (two former employees of Fundación Chile, two employees of IDIEM and a manager of Kuantum, the company that provided the IT services for the development of ReNaM's web platform). We reached these people through a snowball sampling starting with the current coordinator of the ReNaM project at MINVU. In the interviews we asked about their work on the development of ReNaM, their understanding of the purpose of and expectations generated by the ReNaM and its sensors and data, the main progress made, or the problems that have emerged.

We made 13 home visits in three regions of the country: 5 from the Araucanía region, 4 from the Valparaíso region and 4 from the Metropolitan Region. We gained access to these houses through an online form that we designed and that ReNaM sent out to all of its users, inviting them to participate in our research. We received 25 answers of users who remain engaged with ReNaM. The home visits began with a 30–60-minute interview with the ReNaM user. Other family members spontaneously intervened in the interviews in some cases. We asked the subjects why they had joined ReNaM, the advantages and disadvantages of the project, how they use the sensors and data in their daily lives, and whether they have started or stopped doing certain daily practices because of the ReNaM's sensors and data, among other questions. We then asked the users to show us the sensors so that we could observe the domestic setting and take field notes and photos. These interviews and observations allowed us to study how ReNaM's sensors were situated within the homes and how they affected (or not) the mundane practices of their inhabitants.

The analysis of secondary materials included brochures and reports from ReNaM, technical documents, tenders and ministerial resolutions from MINVU, reports from the counterparts, press coverage, user manuals and Terms of Service of the ReNaM sensors, among others. These documents are publicly available on the web, while some were recommended by the interviewees.

All interviews were transcribed and analysed thematically along with the secondary materials and field notes using the qualitative software Atlas.ti. Codes

were generated in the process around ReNaM's objectives as identified by the stakeholders along with their motivations, uses and understandings of the devices and any breakdowns and difficulties mentioned or observed.

Unfolding a Sensor Network

ReNaM is a project of the Technical Direction of MINVU, specifically the Executive Secretariat of Sustainable Building (Secretaría Ejecutiva de Construcción Sustentable, SECS). Created in October 2012, SECS's mission is to coordinate the various government ministries through the comprehensive promotion of the concept of sustainability in the planning, construction and operation of buildings, seeking to minimise the impact on the environment and on people's health.

A bidding process was held for the development, instalment and maintenance of a network of sensors in 2014. Fundación Chile (FCh), a non-profit organisation focused on business development for sustainability and competitiveness, was selected as the counterpart. In 2015, FCh started an open call for volunteers. Those interested had to fill out an online form, indicating the characteristics of their home, and then sign a letter of commitment in which they accept the data collection and agree to maintain the sensors connected. The network grew considerably in 2017 through an open call on social media and contact lists managed by MINVU services. This effort resulted in the installation of sensors in 300 homes in five Chilean cities: Antofagasta, Santiago, Valparaíso-Viña del Mar, Temuco-Padre Las Casas and Coyhaique. The selection of cities and final participants were defined based on socio-economic criteria and geographic and climatic zones of interest. In 2018 a new bid was launched with IDIEM as the main candidate as the next counterpart. The Center for Research, Development and Innovation in Structures and Materials (Centro de Investigación, Desarrollo e Innovación de Estructuras y Materiales, IDIEM), an entity housed at Universidad de Chile that focuses more on issues related to construction. In the future it is expected to scale the project up to over 500 homes and add another city to the network.

Eight environmental measurement devices from Chile and abroad were tested for the ReNaM initiative. After the trials, it was decided to purchase the Smart Weather Station developed by the French company NetAtmo. Founded in 2012, NetAtmo specialises in the design and development of interconnected electronic devices to make homes smarter, that is, homes that are safer, healthier and more comfortable The Smart Weather Station measures the temperature, noise, humidity and air quality (CO_2) within a home through two modules, one for the exterior and the other for the interior. The latter has a luminous indicator that changes colour based on the CO_2 levels in the environment, alerting when the house should be aired out to reduce pollution levels. NetAtmo also designed an app to monitor the environmental

performance of the home in real time, view weather forecasts and receive warnings regarding extreme values so that people can generate healthier environments.

For some SECS members the NetAtmo device was the 'ideal technology' (Gabriela, SECS) for ReNaM because of its low price, ability to measure various variables at once, capacity for remote data transmission via Wi-Fi and the fact that it is not invasive because it is 'made for domestic use' (Pedro, SECS). However, its functions highly oriented towards the adaptation of individual lives and homes, became problematic for ReNaM, as we will see later on. In addition to the expansion of the NetAtmo Weather Station, new monitors manufactured in Chile were added to the ReNaM arsenal in 2017 to measure particulate matter and electricity consumption. However, this process is still incipient and the vast majority of sensors implemented in homes are Smart Weather Stations.

ReNaM from Above

Our exploration of ReNaM elucidated different ways of imagining and materialising it from the entanglement of sensors and data, governments and technology firms, homes and their inhabitants. Following Akrich (1992), in the design of every technical object, its designers try to inscribe 'scripts' about how, and to what ends, the artefacts should be used and inserted in the medium. These scripts reveal projections and aspirations, prejudices and desired scenarios about how the actants – human and non-human- should relate to the artefact. In the case of ReNaM, three explicit scripts were developed and discussed by the project managers. Each of these scripts emphasises different aspects of the experiment, manifesting divergences in the objectives and desired scenes of use, the expected user participation, the value of ReNaM data, and what can and should be made perceptible or sensitive by means of the sensor network.

A Sensor Network for Realistic Public Policies

ReNaM was initially designed to obtain data to improve the Chilean government's sustainable construction policies. The project is thus described as an innovative effort within MINVU. First, it is seen as representing a break from the traditional approach that had characterised housing policy in Chile, which was strongly focused on the housing deficit or quantitative aspect, that is, the need to build more and more homes. ReNaM sensors would allow experts to include and monitor qualitative aspects of homes such as the air quality or thermal insulation.

Second, ReNaM data would promote an innovative 'adjustment' or 'calibration' of housing policies. Pedro, a member of SECS who has actively participated in the management of ReNaM, told us that MINVU has traditionally

followed a 'predictive model' based mainly on expertise in construction physics, computer simulations and laboratory experiments with small samples for limited periods. However, these predictions would always move away from what happens in reality. As various SECS members noted, no computer or laboratory could replicate the series of human and non-human factors involved in the environmental behaviour of a house. Following the justifications of test-bed and *in vivo* experiments, ReNaM would constitute a radically different 'realistic model' using Pedro's words. It would allow for the monitoring of the actual use or operation of homes throughout their life cycle, allowing experts to 'test and touch reality' (Pedro, SECS). This would help identify the gap between what was projected and what people experience in daily life. Furthermore, ReNaM would be massive in nature, including a large number of households and environmental variables at the same time and covering different geographic areas continuously over time.

ReNaM would thus allow MINVU to address questions such as: Which cities and types of housing present a better average index of good environmental performance? How much would it cost to maintain an optimal environment in homes in terms of efficiency or sustainability? What are the health returns of a given thermal insulation policy? As Pedro (SECS) explained, ReNaM would report temperature differences between rich and poor houses and thus allow government officials to make decisions about new thermal insulation or heating policies, estimating the heat needed to improve the temperature of poor households and calculating the 'returns,' such as the degree to which respiratory problems would decrease. Expressing the calculative and economic capacities of ReNaM, Pedro told to us, 'having real data allows you to calibrate and modify certain programs so that they cause the greatest possible positive impact at the lowest cost' (Pedro, SECS).

Third, ReNaM has been invoked as a way to test and demonstrate the positive effects of housing regulations. In particular, members of SECS repeatedly mentioned that ReNaM data allow them to see the positive impacts of changes introduced in the general building code that establishes higher standards and requirements for thermal isolation in home construction. Homes built after the implementation of these requirements come closer to reaching ideal levels of environmental comfort. 'That's where you have a real proof. Not in the laboratory, not in academia, not in a simulation, a real proof of an improvement' (Pedro, SECS).

In this script, it is possible to see the sensor governmentality discussed above. ReNaM produce knowledge that would allow an imperceptible and continuous government of ranges and curves of normality that was not possible before. This sensor network, in other words, is seen as a way to move from the State imposition of fixed standards to a form of regulation based on massive and real knowledge of digital data, calibrating and fostering factors that allow the occurrence of the desired behaviours. In this sense, the objective is not to

coercively impose or prohibit certain environmental practices, but to allow them to occur in order to study them experimentally in their reality or naturality and from there define new and more dynamic public policies and housing regulations and demonstrate their efficacy.

A Sensor Network for Scientific Research

ReNaM also involves the generation of an open database that would allow for progress to be made in Smart Cities, including the development of academic initiatives, entrepreneurship and innovation. The project coordinators have emphasised that this open database will allow researchers to study the Chilean houses in a new way. In fact, some research projects have already developed using ReNaM data to study energy poverty and quality of life inequalities and to model household archetypes (see Urquiza *et al.*, 2017; Becerra *et al.*, 2018; Molina *et al.*, 2020).

However, despite this ambition of using ReNaM's sensors and data for scientific researches, the project did not focus on the accuracy of the measurements at the beginning, and a certain margin of error was accepted. This suggests that the data obtained would not yet have the quality required for academic circles. According to some interviewees, this is related to the fact that ReNaM's creators had a 'more political vision' (Gabriela, SECS). The initial idea was to reach as many houses as possible to show an attractive national policy following the massiveness mentioned in the previous script.

This subsequently raised questions regarding the steps taken to control and reduce the bias and uncertainties in this experiment. The choice to use a consumer-grade monitor like the NetAtmo weather station instead of other more accurate data loggers used in scientific projects led some project managers to doubt the true academic value of this sensor network. As one interviewee points out, this monitor was 'conceived for another purpose. It is not meant for more academic data collection, understand? It is only for domestic use.' (Rocio, IDIEM) Furthermore, at the outset there was no discussion about how to calibrate the sensors with other formal measurements or how to make strong installation protocols and surveys for the scientific community (Pedro, SECS). Moreover, connected to a recurring issue in testing and test beds (Pinch, 1993; Engels et al. 2019), there was no discussion on how to reach a representative sample of the population. This became a problem when more monitors were added without having a clear idea of how many more were needed. So although the questions seen in the previous script are also relevant for this script, here technical requirements are added to be able to develop valid scientific work with ReNaM that were not previously considered.

Despite these weaknesses, people within SECS have insisted on the scientific value of ReNaM. Thus, as Gabriela points out, 'some professionals believe that simulation is enough to define regulations. Those of us who worked on ReNaM

are of the idea that this has to be validated with monitoring, real building, seeing how it behaves.' (Gabriela, SECS) Likewise, efforts have been made to adjust ReNaM to scientific requirements. An area called ReNaM Lab was created to encourage scientific research on housing beyond the ministry and test new protocols more aligned to academic standards on a limited set of houses to expand them in the future to the entire network.

Here we begin to see differences between State and scientific priorities and how ReNaM has adjusted its protocols and ways of understanding its data to add greater control over uncertainties that did not seem very relevant in the first script. In other words, the search for massive data on the real operation of homes was not necessarily aligned with the emphasis on precision and representativeness from this second script. Precisely, the future corrections to their protocols seems a way to resolve the friction between these scripts. But, even with these frictions, governmentality is strongly evidenced in these two scripts focused on capturing real-time data about the real domestic life at a distance.

A Sensor Network for Changing Habits and Empowering the Users

A third script emerged through the idea that the data gathered by the sensors can help to change users' behaviour, for example, in regard to energy consumption, ventilation or insulation of homes. As Gabriela stated: 'We hope to drive changes in behaviour, raise awareness and educate the public through this effort.' According to several actors, this objective emerged along the way. Luis, a former Fundación Chile project manager, told us that between 2016 and 2017, 'the user began to be empowered […]. People wanted to know more, understand what was being measured. They didn't want a device that measured something without knowing what.' This led Fundación Chile to make some changes to the way that the project was implemented:

> the government and universities don't involve the users a lot when they conduct these studies. We said no, that they have to be involved because if we want *good data* and for the project to last, the user has to be involved in everything. (Luis, Fundación Chile)

In order to further involve or 'empower' users, they started to suggest the use of NetAtmo app and send weekly reports to the users on their average performance with red or green colours if they were out of normal ranges. A 'Guide to Improving Habitability' was designed that specified ideal comfort ranges, provided advice for achieving them and described the health effects of falling outside of those ranges. The idea was to make people aware of how much the poor environmental quality of their home could impact them and to help them identify strategies for improve thermal insulation and reduce energy consumption.

The information is thus enacted as a trigger for people to self-regulate and change their habits and homes based on the data so that they live in a more pleasant and healthier environment. The coordinators of ReNaM projected a

similar user to the dominant ideal consumer enacted in energy policy and consumer research – a human male adult who makes efficient, rational and autonomous decisions about the sustainability of his home using digital data (Strengers 2013). In this way, this script, while following another approach to the population, it does not deviate from the neoliberal rationality of governmentality. It continues to advance the idea that people should conduct themselves properly with the correct incentives and encouragement of environmental data (Miller and Rose, 1990). Projected ReNaM users are free to exercise personal choice regarding which sustainable changes they implement in their homes, but they are expected to embody the rational and efficient control on their domestic consumption according to the data provided.

However, this way of materialising ReNaM was not shared by everyone. In fact, some brochures identify generating data to improve State policies as the only objective of ReNaM. For Miguel, a former SECS member, the goal of helping users to improve the environmental quality of their homes was not so relevant in ReNaM. Instead, it was just the 'great theoretical hook' for capturing volunteers, and real changes in habits or homes were only anecdotal cases. For others, this form of materialising ReNaM is even seen as harmful for the previous scripts of adjusting MINVU policies or obtaining scientifically correct data. Greater interaction between users and sensors could affect the validity of the data by failing to capture the 'real' conditions of use of the home.

Here is strong friction among the scripts previously discussed regarding the accepted interactivity between the monitoring devices and the monitored homes. While the first two scripts promote the idea of capturing data about the 'real' environmental behaviour of homes with as little involvement as possible by users, the third one emphasise capacities of ReNaM sensors and data for raising awareness or 'helping' users to achieve greater efficiency and sustainability in each home, shaping in the process the 'normal' behaviour of homes.

ReNaM from Below and Mundane Entanglements

Until now, our story has focused on how the ReNaM was deployed 'from above' in the territory and the divergent ways in which the officials understand the purpose and uses of this sensor network. However, within the homes in which these sensors were installed, we found a multiplicity of domestic and everyday entanglements with a whole spectrum of motivations, understandings and ways of relating to the ReNaM's sensors and data, ranging from a total disinterest to intensive use of the data to make changes within the household.

Contributing Data to the State

Several users indicated motivations for participating in ReNaM aligned with the first script, such as 'contributing' to the State's statistics and improve its policies

and regulations. Users valued the effort of MINVU in collecting data from local contexts of their neighbourhoods, cities and regions. For instance, Enrique from Quilpué criticised the deep centralism of Chile so he found it positive that ReNaM included the reality of his region, making him feel more 'part of a system'. On a more local level, several users from Temuco, aware of the heavy pollution by wood heating in the winter, decided to participate in ReNaM to contribute data for better decontamination plans for the city. For these users, it was good that the MINVU managed to 'learn about how we live' (Eduardo, Temuco) as a way of making their reality visible to the State.

Following this purpose, some users were indifferent to the sensor and only worried about keeping it connected and emitting data. Users celebrated the non-invasive nature of the NetAtmo device, describing it as a 'quiet' or 'low profile' gadget that mimics domestic objects. In fact, sensors were placed behind family photos or televisions, making them completely unnoticed. This indifference to the presence of the sensors would be ideal for obtaining real data for the policy and scientific scripts. For example, Claudio from Macul said that he had 'played' with the app and the sensor but quickly lost interest in them. 'I feel like [the data] are helping someone, but that there is no benefit within the home.' But despite that this user indicated no benefit, he mentioned that the monitor had helped him gain awareness and reduce CO2 levels when cooking or the noise his dog made at night when barking at passers-by.

Contributing Data to the Home

Along with the 'altruistic' motivation to contribute data to the State, other users also indicated more personal or 'selfish' intentions as one interviewee called it, focused on knowing the environmental performance of their home for their own purposes and experiments. The most illustrative cases of this were the tech-savvy users who had their homes equipped with systems of home automation and smart assistants and they sought to continue 'technologizing' their houses. So part of their motivation for participating in ReNaM was to get the NetAtmo device for free and leveraging all of the potential of it.

For instance, Luis from Maipú describes himself as 'a little obsessive' about data. He checked the NetAtmo app every day and saw it as a 'fairly powerful tool for being able to make improvements around the house.' Based on the ReNaM data, he changed the carpets in his bedroom and use a special vinyl floor to reduce noise. He also installed a roof on his patio to decrease the temperature. Another example was Pia, who lived with her partner in an old cabin near the coast in the region of Valparaiso. For her, the measurement of CO_2 was 'sacred' and motivated her to periodically ventilate her house to achieve a good space to work from home. But after seeing in the app that high levels of humidity continued to be registered even though she made changes to her house like sealing the windows with silicone and changing the curtains, she decided to move to

another city in the region. This form of participation would be more in line with the third script, as these subjects of the experiment change their habits and were more proactive in self-regulation processes driven by the collected data.

Re-Purposing Sensors and Data

In the middle of this spectrum, we found practices that escaped the scripts programmed in the experimentation. For instance, in the letter that the participants had to sign, they had to commit not to move the sensors from the position that ReNaM agents had selected (mainly living rooms) so as not to affect the measurement. However, in most of the homes we visited, users moved the sensor. Some users moved the sensors believing that in the original location they wouldn't capture the 'true heat conditions' (Luis, Maipú). Others moved the sensors to measure areas of the house that they were more interested in, such as bedrooms, or to experiment with it to test how to better heat their apartment or ventilate some rooms.

We also found more varied uses than those drawn above. In addition to utilising the sensors to know when to open the windows and ventilate the house, several users said that the measurements help them to monitor their homes for possible robberies that would be indicated by increases in noise levels or CO_2 when no one was supposed to be home. As Simon from Quilpué points out, 'the sensor doesn't look for that function [security], but you still adopt it.' Also, multiple users noted that the sensors helped them care for their families, particularly in regard to monitoring temperatures, internal pollution or humidity in homes with children or babies. For example, Pamela from Temuco was interested in knowing how cold it was on the second floor of her house and experimenting if the changes made to the thermal insulation were working or not, especially considering that she had a new-born. Alejandro from Quilpué was interested in measuring environmental variables in his home such as temperature or humidity because he has a child with cerebral paralysis: 'He can't really express how he feels. The only thing we know is that he is very cold because when you touch him he is frozen […] and then when you see the data, yes, it is [cold]' (Alejandro, Temuco). These practices of care take us away from economic calculations and reveal how the sensors were domesticated and contribute to more experimental, intimate and affective entanglements that go beyond public policy or academic research.

Furthermore, by looking at this ReNaM from below, it becomes necessary to refute deterministic views that sensors and data would directly cause changes of habits and habitats.

In contrast to the third script, several users stated that the data helped only to verify their previous intuitions and feelings about the environmental behaviour of their homes. For example, for Claudio (Macul) the sensor helps to say, 'hey! It is really cold. It isn't just us!' Alejandro (Quilpué) told us that his house surely had insulation problems because it was very cold in winter. 'I knew it was [cold], but

here [with ReNaM] it became evident that there is indeed an issue based on the numbers.' Returning to Pia's case, the data served to verify her sensations of cold, humidity or noise levels and to say 'I'm not that crazy, right?' So her decision to move to a new house was informed by ReNaM data as well as other sensory sources such as the presence of mould on the furniture or her own senses, in a kind of more-than-digital sensitivity. In this sense, the data offered by ReNaM's reports or NetAtmo's app justify and encourage certain actions but that were already thought of or experienced by the habitants of ReNaM's homes.

Disconnections

Alongside these multiple forms of living with sensors, various issues emerged such as interruptions or failure to comply with the ReNaM scripts. The coordinators monitor from a dashboard the sensors that are disconnected or that present values outside the normal range. In these cases, and due to the costs, the staff merely sent an email or called the user to ask them to reconnect the sensor. 'The idea isn't to invade anyone's home.' (Pedro, SECS) Multiple domestic entanglements were responsible for these decalibrations or disconnections. Sensors were unintentionally unplugged when cleaning the house or by children while they were playing. The USB power cable was short so it was easy to disconnect. In addition, some users used the cable to charge a cell phone and then forgot to reconnect the sensor. When the electricity or Internet service was interrupted or the resident changed their Internet provider or Wi-Fi password, the devices stopped transmitting data. Users only noticed that the sensor was disconnected when they received the weekly report indicating that there was no data.

In sum, from this ReNaM
from below, we observed alternative uses, re-orientations, more-than-digital sensitivities, and forms of disruptive involvement or occasional 'idiocies' (Gabrys, 2016; Tironi and Valderrama, 2018) of the home inhabitants in their daily living with the sensors. The diverse forms of participating in the experiment slow down and make more precarious the intention of deploying these digital innovations in order to articulate smarter forms of government of the territory. While ReNaM saw carefully managed distance monitoring as an experimental process of governance, these forms of participation reveal events that were impossible to predict and programme, showing how people *do* and *undo* the experiment in, and through, their everyday life.

In this sense, the imagined user in the third script, who engages in rational autonomous actions driven by data, is displaced by the multiple modes in which inhabitants of ReNaM's homes negotiate and domesticate the sensors based on their particular needs, contexts and previous sensations. Instead of being merely conducted towards economic calculations and changes of habits, users were indifferent or re-purposed the sensors for affective and mundane practices. And even when we some users declared some changes in their habits and

habitats, these they weren't driven solely by ReNaM data and sensors. This forces us to reconsider the particular ways in which the subjects under study in these experiments in living, with all their lively realities, challenge and displace the real-world conditions defined by the experimenters. All the instances of domestic interactivity between sensors, data and inhabitants were not only invisible in the dashboards of ReNaM, but also were not considered relevant for experimenters. Only recently, with this initiative of a ReNaM Lab that we mentioned above would they be opening up to study these practices, in what would be a promissory laboratory within a laboratory in the real world.

Conclusion: Sensor Invasion, Participation and Realness. Towards More Speculative Forms of Digital Sensing

Based on a smart logic, digital innovations are penetrating diverse environments, situating themselves in everyday spaces like our bedrooms and living rooms, making it possible to conduct new experiments and regulations in them from a distance. In this article, we have proposed the notion of sensor governmentality to describe and analyse the ways of knowing and governing domestic life that became operable through participatory and real-world experiments with digital innovations like the case of ReNaM.

The installation of sensors in the territory follows the double meaning of conduct suggested by Foucault (2007): the everyday environmental behaviour or conduct of each home is made quantifiable and calculable through this real-world experiment. And at the same time, with this, it is possible to conduct such conducts to increase the probability of favourable returns, either through the effort to change habits or in the development of State policies on sustainable construction. Instead of being based on distinctions between what is permitted and what is prohibited, nor on the disciplinary impositions, this form of governmentality is characterised by the imperceptible and continuous regulation over always changing ranges or curves of normality monitored by sensors. More than in algorithms, which in the case of ReNaM we did not find much development, we emphasised the sensitive character of this form of governmentality that unfolds technologies capable of being sensitive and registering a multiplicity of sensory phenomena on a certain scale. In other words, the ReNaM experiment allows domestic experiences to be translated into a series of variables that can be monitored and regulated in order to economise the environmental behaviour of homes.

However, far from reducing this monitoring network to a unidirectional, friction-free and univocal operation of economisation, this sensor governmentality is inevitably multivalent. Divergent scripts were found around how to define this sensor network, what would be good data and the type of participation that actually counts within the experiment. As we have shown, MINVU is unfolding this sensor network to obtain a more realistic and massive knowledge of the environmental behaviour of homes over their life cycle. Plans, designs and

ways of engineering innovations cannot consider or predict all of the aspects of the real world, which means that they must be tested in real situations first (Pinch, 1993). In our case, the traditional boundaries between the creation of housing policies and regulations and their actual implementation are deliberately blurred by testing and monitoring real-time data.

But this policy orientation of ReNaM diverge from the academic interests of obtaining scientifically accurate or representative data that could be used for studies and initiatives beyond the State. As we discussed in regard to the second script, ReNaM faces problems to define a truthful representation of society, not only in the representativeness of its sample but more profoundly in what counts as real-world conditions for testing and the ideal technologies to capture them (Engels et al., 2019). Both the government and scientific scripts presented frictions with the participatory script that defends the supposed empowerment of ReNaM users already inscribed in the design of the Smart Weather Station by NetAtmo or by sending weekly reports to users. These three scripts, despite their differences, manifest the sensor governmentality to the extent that they generate a sensitive governance of behaviours at a distance, either through national statistics and regulations or changes in behaviours in each home.

Yet, beyond the different scripts projected by the State, home inhabitants engaged and domesticated the sensors and data of the experiment under the living conditions of each home through multiple and mundane encounters from below. The expected rational user who change their habits or homes driven by the data in the third script, only appears as one way among many others to get involved and participate in ReNaM if we consider how people verified prior sensations, disconnected the sensors by mistake or repositioned and reoriented them for other purposes. The conditions of the experiment are always awkwardly disturbed because of a heterogeneous range of practices, motivations and more-than-digital sensitivities produced in the interweaving of home, sensor and inhabitants, making the data a situated achievement of complex arrangements in which they are made to exist.

Therefore, the participation in this sensor network cannot be limited to an area of economic involvement. The process allows actions in a wide number of registers at the same time: it co-articulates participation in political, sustainable, economic, scientific, affective, and mundane issues and spheres, among others (Callon et al., 2009; Marres, 2012), manifesting the need to manage divergent objectives. This case shows that real-world and participatory experimentations have to deal with traditional aspects from laboratories such as reproducibility or representativeness but at the same time they have to maintain an openness to the unexpected intersections of different spheres of living. But far from constituting an issue analysed by those responsible for strengthening the scope of experimentation, this multivalence gives the project a certain fragility. As we have indicated, significant frictions arise between the scripts around how to manage the invasiveness of State sensors in homes and what would be the real way of behaving in homes.

This leads us to consider how actual participation is scripted in real-world experiments and to speculate on alternative forms of involvement. First, ReNaM's participants were only involved in the data collection stage, do not receive remuneration for their work, and have not been informed of the overall experiment results. This stands in contrast to other participatory monitoring projects in which the active participation of people is strongly considered, redistributing the epistemic authority or agency over knowledge in truly experimental ways (see Gabrys et al., 2016; Jiang et al., 2016; Marres, 2017). This allows us to ask what would have happened if the ReNaM participants had been involved, for example, at the beginning of the process, selecting or even developing the sensors to be used in the project.

Second, ReNaM consider only the participation of individual humans, which nullifies any possibility of achieving the collective potential of the citizen sensing (Pritchard and Gabrys, 2016). There is no desire to articulate this sensor network as a way of forging communities in ReNaM, partly because the experiment did not start from problems shared by citizens, but was instead meant to achieve greater data massiveness throughout the territory.

Third, the possibility of activating new ways of becoming sensitive to daily problems inside the houses is not considered within ReNaM. The affective, mundane and bodily attunements between sensors, data and the inhabitants of ReNaM's houses seem not to be relevant for government officials, without readapting their scripts with the particular uses and sensitivities of the inhabitants. In this way, the hierarchical structure of knowledge based on the authority of numerical data continues to be privileged (Calvillo, 2018; Calvillo and Garnett, 2019).

In more general terms, the efforts of ReNaM to reduce interaction with users and make the invasion of sensors as imperceptible as possible in order to guarantee the supposed realness of the data manifest the neoliberal rationality of intervening as little as possible present in real-world experiments. Going back to the field note included at the beginning of this article, the fact that the NetAtmo sensor is hidden among souvenirs or family photos or goes unnoticed while it is collecting data is intentional, a way of formatting the possible entanglements within the sensor network. In a way, the success of these real-world experiments would be to control the environment and the inhabitants' participation to secure assent that what they are measuring is real behaviour.

But at the same time, the multiple and lively realities participate and react to these experiments, affecting what is defined as the real conditions of the world. Forms of engagement in experiments such as misbehaving or using sensors for unanticipated purposes can be understood as sources of greater reality rather than sources of major biases that reduce the realism of the data. As such, rather than seeking indifference to the sensors or making insignificant the invasion of the household, sensor networks can unfold speculative experiments based on the surprising or unexpected. They can become open to the design

and redesign of homes and their human and non-human inhabitants, incorporating and mingling technical aspects with sensorial, affective and collective elements, thus promoting and valuing interaction between the researchers and the research entities to make new future realities.

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Notes on contributor

Martín Tironi is a sociologist, Pontificia Universidad Católica de Chile, 2006. Master in Sociology, Sorbonne V, 2010. PhD, Center de Sociologie de l'Innovation, École des Mines de Paris, 2013. Post-doctorate, Center de Sociologie de l'Innovation, École des Mines de Paris, 2014. Visiting Fellow, Center for Invention and Social Process, Goldsmiths, University of London, 2018. His research areas are anthropology of design, digital devices and technologies, and urban infrastructures. His work has been published in The British Journal of Sociology (2020), Journal of Cultural Economy (2018), Environment and Planning D (2018), among others. He exhibited the installation "Ashes of coexistence" at the Museum of Contemporary Art (Biennial of Medial Arts 2019) and is currently preparing the curatorship of the Chile Pavilion for the London Design Bienale (2021).

Matías Valderrama is a sociologist and Master in Sociology from the Pontificia Universidad Católica de Chile. His currently working as a research assistant on the research project (Fondecyt, 2018-2021) titled 'Datificación of urban environments and individuals: an analysis of the designs, practices and discourses of the production and management of digital data in Chile'. His research areas are Digital Culture, Science and Technology Studies, Surveillance Studies, Social Movements, Digital Methods and Social Network Analysis, among others.

ORCID

Martín Tironi http://orcid.org/0000-0001-6569-9527
Matías Valderrama http://orcid.org/0000-0003-0631-2454

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