ABSTRACT

DUARTE, FERNANDA DA COSTA PORTUGAL. openAnalogInput(): Hybrid spaces, Self-making and Power in the Internet of Things. (Under the direction of Dr. Adriana de Souza e Silva.)

This dissertation investigates how the emergence of the Internet of Things and the embeddedness of sensors and networked connectivity onto things, physical spaces and biological bodies rearticulates embodied spaces, devises practices of self-making and forms of power in the governance of the self and society. In the Internet of Things, the development of pervasive computing applications has enabled computing capacities to be discretely distributed across environments and bodies. Personal data collection and big data mining traverse all dimensions of life and create forms of knowledge that integrate data embodiments of multiple scales. Personal data from an individual creates a data double of her physiology; data lakes of traffic patterns, consumer habits, are correlated to create demographics predictions. The consequence of this seamless geared informational design is twofold. While networked data processing becomes more efficient and manageable, it also becomes more complex and more subtle. Simultaneously, as pervasive computing capacities allow networked technologies to be available on the go and activated by individual subjects, these same individual subjects also act as bodies that are integrated into the networked environment and subjected to its asymmetrical power dynamics. This study investigates: (1) how embodied spaces are built upon data mining strategies through the production and correlation of aggregated data, (2) the practices of self-making that emerge with the Internet of Things, and (3) the forms of power at work in the biotechnological topologies of the Internet of Things. In this dissertation I adopt a materialist framework that reconciles perspectives in the fields of Digital Humanities and Critical and Cultural studies to discuss

media technologies and networks as a procedural material articulation of discourses, social practices and actions. This dissertation follows methodological guidelines of Grounded Theory (Charmaz, 2006) and addresses the research questions through a tripartite method approach. (1) I started this investigation through auto ethnographies to produce accounts of my use of self-tracking technologies. (2) Based on this initial experiences, I developed a critical making experiment titled "Truth or Dare: a moral mobile compass for ethical living" (ToD). ToD is an interactive installation that mimics the function of a lie detector. In this installation I installed analog sensors in a micro-controller that when held by the installation participant produce values that measure her emotional distress (similarly to a typical lie detector, emotional distress is measured based on the variation of electric conductivity). The values are relayed to an app in a smartphone that interfaces with Twitter. As the participant tweets, the app inputs how her values fall into the threshold of distress. If the value is off range of the baseline for normalcy, the app tags the tweet with #lie. ToD produces an ironic and critical approach to the adoption of biometric and computational parameters for the construction of truth and reveal a wide range of symbolic negotiations that shape the construction of mediated subjectivities. (3) And lastly, I also observed discussion threads of the online forum of the Quantified Self movement, which is a community of "self-trackers" that mostly uses sensors and wearable computing for self-knowledge and life-logging. This dissertation contributes to the fields of Digital Media theories and Cultural Studies by developing further critical making as a method that can overlap social-political perspectives with discursive and material analysis. Through this dissertation, I also argue for further interdisciplinary collaboration among the fields of Humanities, Social Sciences and Computer Science to nurture further debates about the social, ethical and political implications of new media technologies, specifically regarding data mining practices and physiological information.

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openAnalogInput(): Hybrid spaces, Self-making and Power in the Internet of Things

by
Fernanda da Costa Portugal Duarte

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BIOGRAPHY

Fernanda Duarte was born in Belo Horizonte, Minas Gerais, Brazil in 1982. She graduated with a Bachelor of Arts in Communication/Advertising in 2003 at the Pontifical Catholic University of Minas Gerais (PUC Minas). After a few years working with online education at PUC Minas, she received a Master of Philosophy in Communication from the Federal University of Minas Gerais. Fernanda worked for five years at the State Government of Minas Gerais as a Director of Public Policy for Higher Education at the State Secretariat of Science and Technology before moving to North Carolina, U.S., to pursue a PhD in Communication, Rhetoric and Digital Media. Her research interests revolve around issues of digital media, specifically subversive appropriations of technologies by media artists and activists. From her undergraduate experimentations with net art, her thesis research on interface design and software art and now her doctorate experiments with physical computing, her research methods have often implicated in critical making (or *fazer crítico*, as it is referred in Portuguese). Fernanda Duarte believes that innovative research and teaching must mobilize sensorial, speculative, intellectual and tacit inquiry.

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Five years ago, I moved from Brazil to North Carolina, where I had never set foot before. In my time here I met wonderful people who accompanied me in my research, who shared with me life-changing experiences and who I will forever hold on my heart.

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In these five years, I serviced in the office of two student associations on campus, the Latin American Student Association, the Fulbright Student Association, and with the Office of International Services, in welcoming incoming international students and educating about Brazilian culture. These opportunities introduced me to a wide range of cultures and amazing individuals. I appreciate the friendship of all LASA members and Fulbrighters I had the chance to meet. I am eternally grateful to the Office of International Services for the support as a student as their Communications Intern. I want to thank Lauren, Thomas, Beth, Kelia, Stacy, Carl, Alex, Mollie, Anna Grace, Hillary, Alexis, Dina, Rebecca and Tim for their friendship, for the donuts and for the nurturing work environment.

The presence of my family has been a constant in my life and I am lucky to have them always on my side, even when not physically close. My mom, Mauricea, my dad, Roberto, my sisters, Daniela and Mariana, my brother-in-law, Igor, and all my extended family and friends have always been cheering for me. I express here my love for them and my gratitude for their unconditional love and support.

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LIST OF ABBREVIATIONS

IoT = Internet of Things

ToD = Truth or Dare installation

GSR = Galvanic skin sensor

GPS = Global Positioning System

GIS = Geographic Information Systems

Xerox PARC = Xerox Palo Alto Research Center

TCP/IP = Transmission Control Protocol/Internet Protocol

VR = Virtual Reality

HCI = Human Computer Interface

INTRODUCTION

With both hands over my stomach, I breathe in and feel the air take over the full capacity of my lungs. I count a few seconds and exhale letting out heavy air. I breath in and visualize the air entering my body through my feet and slowly taking over the entire internal space of my body. I count a few seconds and I breath out and notice the amplified space the air left behind. I breath in and I wonder if I am keeping the correct count, other people in the room seem to exhale before I do. I decide to breath out and wish the sensor I am wearing could vibrate to assist me with the breathing count.

Thirty minutes of daily meditation for eight weeks and constant use of a wearable self-tracking device. The practice of self-awareness, yoga, loving kindness, walking meditation and mindfulness are part of a research study I participated in the Fall of 2012 at Duke University that investigated the effects of meditation and increase of self awareness in the reduction of stress. I was asked to practice meditation for two months everyday, maintain daily logs of my physical activities, overall mood and level of energy. I also wore sensors attached to a wristband that kept track of my sleeping hours and sleep quality. The wristband gizmo had a light sensor and an accelerometer. As it detected no source of light, the device assumed I had prepared to go to bed and marked that stage as "start of sleep." It then watched for the lack of movement detected by the accelerometer as an actual mark of sleeping activity. Throughout the days, the data demonstrated the average time it actually took me to fall asleep once I got in bed, how many times I woke up during the night, and how many hours of restful sleep I actually got. With that data, my personal observations about my mood and my daily logs, blood tests and EKG exams before and after the eight weeks of meditation, I was given a broad portrait of my self. I was faced with an eight-week worth of organized memory of how I felt and how my body performed and was affected by the changes in my routine. As I left Duke hospital with a detailed report filled with numbers and graphs of my accumulated data I could not help but feel empowered and filled with a sense of self awareness. I can always count on my subjective perception of my body and the memory of my feelings but as they faint or get confused, I can rely on the numbers and the logs to more accurately recall the events of a day.

Around the same time, I experimented with collecting personal data—through wearable sensors—and logging my life, other tracking devices were made available on the market. In April, 2013 Google made the first version of Google Glass available to early adopters and Samsung, Motorola, and Sony Ericsson released smart watches that were powered with biosensors and also synced with smartphones. Groups of users and makers of self tracking tools, such as the Quantified Self,[1] organized online communities with forums, depositories of videos, reference guides, and gadget reviews to share knowledge and best practices of collecting and analysis of personal data. Open source, DIY small sized physical computing kits and biofeedback sensors, such as arduino and raspberry pi, became more widely available and fostered increased experimentation with making wearable technologies.

While the concept of self-tracking itself is not new—it can be argued that journaling and confession are strategies to monitor oneself—the use of pervasive computing technologies to keep record of activities and manage life itself is quite recent. In 2012, Gary Wolf and Kevin Kelly, both editors of *Wired Magazine*, started a website[2]

[1] http://quantifiedself.com/
[2] http://www.quantifiedself.com. Retrieved in December 2014.

to gather the growing community of self-trackers and to provide available resources on self-tracking tools, recommend literature, promote local meet up events across the U.S. and show and tell conferences. Earlier in 2010, Gary Wolf had published an article[3] in the New York Times Magazine entitled *The Data Driven Life*. In this article he provided a compendium of personal stories about tracking physiological data and logging daily activities such as sleep, diet, mood and location using wearable computing, biometric sensors, logs, and any tools capable of producing quantifiable data about a body's performance. The Quantified Self platform is today a major resource for users interested in technological tools that provide monitoring capacities and centralized agency over the performance of the biological body. It is defined as:

> a movement to incorporate technology into data acquisition on aspects of a person's daily life in terms of inputs (e.g., food consumed, quality of surrounding air), states (e.g., mood, arousal, blood oxygen levels), and performance (mental and physical) (...) In short, quantified self is self-knowledge through self-tracking with technology. Quantified self-advancement has allowed individuals to quantify biometrics that they never knew existed, as well as make data collection cheaper and more convenient.[4]

The Quantified Self movement is a community of users that makes use of self tracking tools to gain in-depth perspective of their physiology as well as to monitor other aspects of their routine such as mood, tasks, and activities. The difference between these contemporary self-tracking strategies and prior modes of self-accountability is that they

[3] Retrieved from http://www.nytimes.com/2010/05/02/magazine/02self-measurement-t.html?pagewanted=all&_r=0
[4] http://en.wikipedia.org/wiki/Quantified_Self

are sustained by a digital way of knowing and constructing reality that is sustained by quantification as a field of scientificity (Foucault, 1972). Scientificity is defined by Michel Foucault as the conditions that create the possibilities of what may be characterized as scientific discourse (similarly to Kuhn's notion of paradigm). As I observed how the use of these pervasive wearable technologies allowed the monitoring, record and data sharing of how bodies perform (for example, during fitness activities or illness) I became intrigued about the emergence of a *data driven life* through the adoption and appropriation of these technologies. Such *data driven life* is referred here in the scope of the Internet of Things, IoT (Ashton, 2009) and is characterized by the embeddedness of heterogeneous computer networks in architectural/physical spaces, and bodies of living and non-living things. Such *data driven life* is sustained by the underlying logics of big-data mining, marked by automated collection of large and complex sets of data, processed through automated data analytics for data correlation and pattern recognition (Andrejevic, 2013, 2014; Mayer-Schonberger & Cukier, 2013).

Pervasive computing, the Internet of Things, and data mining are emerging fields with growing research interest. Self-tracking through pervasive technologies has been only widely adopted in the last five years and the wearable computing market shows an estimated growth of 35% per year for the next five years.[5] Previous self-tracking practices, although existent, were confined to academic research and prototyping, such as Steve Mann's project of the WearCam (Mann, 1997) or in medical research for mobile diagnosis or care (Crawford, Lingel, & Karpi, 2015). The adoption of these technologies

[5] See report by http://www.businessinsider.com/the-wearable-computing-market-report-2014-10

and the increasing availability of new devices on the market are an indication that self-tracking practices are a relevant object of study that must be investigated.

The majority of studies regarding pervasive computing and the Internet of Things can be found in the disciplines of Computer Science and Interface Design (Weiser, 1991; Weiser & Brown 1995, 1999; Greenfield, 2006), and they often focus on further technical developments of the technology and privilege questions of functional use. This scholarship provides evidence of a shifting paradigm in personal computing that geared towards individual mobile devices of continuously decreasing size and increasing data processing capacity. These studies are guided towards utilitarian approaches for the development of efficient systems. Ultimately, the research goal is also oriented towards the development of effective seamlessness between the computing interface and the user.

While approaches in Computer Science adopt a functional perspective of technology, researchers in Humanities and Social Sciences have been investigating the implications of the pervasiveness of the internet in the context of mobile media (Dourish and Bell, 2011; Goggin, 2011, Ling, 2004), and the impact of integrated connectivity in the social construction of spaces, places, and locations (de Souza e Silva, 2006; Callon, Law, & Urry, 2004; Gordon & de Souza e Silva, 2011; Russel, 2009; Sheller & Urry, 2006; Silverstone & Sujon, 2005). The creation of GPS and GIS systems, location-based services and networks (such as Foursquare) suggest that the spatial practice of movement is intertwined by a mesh of digital data and physical space. Moreover, as I expand in chapter one, it demonstrates that with the technological protocols of GPS and GIS, a spatial way of knowing also emerges through digital data.

The pervasiveness of digital data and data mining processes has invaded all dimensions of life and created forms of knowledge beyond GIS/GPS. In the past two years, a small (but growing) number of master and doctorate studies in Humanities and Social Sciences have focused on self-tracking practices, and specifically, on the Quantified Self movement. In my literature review, I encountered two ethnographic theses (Butterfield, 2012; Watson, 2013) that approach self-tracking from an Anthropological perspective. The practices observed by these ethnographies focus mostly on life-logging activities, such as journaling, activity management and fitness tracking. I also encountered one book edited in Switzerland that comprises articles about self-tracking and health management (Lupton, 2015), and a few published articles that articulate self-tracking to gamification (Whitson, 2013), and as a form of surveillance (van Djick, 2014, Klauser & Albrechtslund, 2014). A publication in the field of Medical Sciences by Richard Macmanus came out this last August, “Health-Trackers, how technology is helping us monitor and improve our health.” This publication presents a history of consumer devices for healthcare and speculates about how pervasive computing technologies might change the way we care for ourselves and how the health system is formally organized. In the upcoming year, Gina Neff, from the University of Washington, and Dawn Nafus, from Intel Labs, are publishing the book “The Quantified Self” through MIT Press, which presents a history of self-tracking tools and addresses how quantification can enable users to connect and learn from each other. Thus, this dissertation is inserted among emerging research initiatives that are investigating self-tracking practices within the field of Social Sciences.

At the same time that this study complements previous research, it also diverges from the previously applied frameworks. This dissertation addresses a gap in research in the Humanities and Social Sciences to further develop approaches to the Internet of Things that considers the epistemic actions of digital data mining (Packer, 2013) in the construction of knowledge about ourselves and our social reality. This study applies the framework of a digital episteme, defined by Kate Maddalena (2014) as

> a particular media apparatus that constitutes a distinctive way of knowing (…) in the rise of discontinuous, non-semantic, and modular media for the sake of constituting large amounts of information and for taking apart and remaking that information to interpret it (to make new knowledge) and to deploy it (to make new objects). These commitments and their concurrent media practices also function as ways of being, making, and knowing. (p.35)

This dissertation applies Maddalena's framework of a digital episteme to approach data mining and self-tracking practices in the Internet of Things. Simultaneously, this research implements critical making method to explore the potentials and limits of the digital episteme framework.

This study acknowledges that the pervasiveness of digital media across all dimensions of life has shaped processes of knowledge-making accordingly to the epistemic actions of digital data. As overlapping topologies, data mining renders multi-scalar hybrid spaces (de Souza e Silva, 2006) and enacts an algorithmic form of knowledge of our biologies through data correlation. The transcoding of the analog world into binary information creates non-semantic metadata which levels the play field between human and machine actions and allows for the collection and correlation of data.

As subjects construct new objects of knowledge based on new strategies to generate, aggregate, and analyze data, this new knowable reality also speaks about the subjects that are immersed in it. Therefore, I approach self-tracking as more than a data-gathering practice but also as a strategy of subjectification.

The construction of knowledge through digital data is also articulated through the critical making installation "Truth or Dare: a moral mobile compass for ethical living" (ToD).[6] Following researchers of critical making methods (Hertz, 2012, Ratto, 2011, Ratto and Boler, 2014), ToD was built not to operate as a functional mobile app, but instead as an ironic, critical tool to engage, provoke users, and stimulate critical reflection about common sense use of biofeedback wearable technologies. The premise of ToD is that it mimics the function of a lie detector and, as a typical lie detector, is capable of distinguishing between true or false statements based on the user's biofeedback readings. The statements in this case are text-based *tweets*, and the biofeedback information is the measure of electric conductivity on the user's fingertips. ToD is composed by a mobile app installed in an Android smartphone and a biometric sensor that must be held by the user as she interacts with the app. The functioning of a biofeedback-based lie detector is grounded on the basis that electric conductivity of a biological body varies accordingly to emotional states. In situations of stress the nervous system activates the sweat glands and the humidity of sweat on the surface of our skin lowers the skin's resistance to electric current. In consequence, the amount of electric current allowed through the body goes up. The sensors located on the surface of the skin pick up on the spike of the value and this

[6] Pictures of Truth or Dare are available at http://goo.gl/7Bic4x

variation is interpreted as emotional distress. In the case of ToD, the variation of values was arbitrarily defined as correspondent to emotional distress, and likely, as a lie.

To interact with ToD, the user opens the app on her smartphone, allows for her Twitter account information to be synced, holds the sensor in her hand and starts typing a *tweet.* From the moment she opens the app, the sensors are recording the values of electric conductivity as “normal” and defining the average value as a baseline for “neutral emotion.” When the user finishes typing and hits “send,” the app collects a new value from the sensors and compares with the baseline value. If the new value is higher, the app automatically adds the hashtag #lie to the tweet. If the new value is equal or lower, the hashtag added is #true. In chapter two, I provide a more detailed account of the process of prototyping, the conceptualization that inspired it, and the rationale that guided the execution of the interactive installation. I also expand on the description of the actual device, the setup of the exhibits and the interactions with participants.

The ToD installation explored how computational parameters for the construction of truth reveal a wide range of symbolic negotiations that shape the construction of mediated subjectivities. Moreover, the adoption or negation of the outputs produced by ToD (#lie or #true) crafted the participants’ identities as truth-tellers or liars, and enacted how digital technologies can be appropriated as a form of self-governance (Foucault, 1997, 2003). It also speaks of the symbiotic relationship between digital technologies and quantification (as a measure of truth and as a measure of self), as sustained by a circuit of reproduction of a digital episteme (Maddalena, 2014) founded upon discrete numeric information that can be aggregated and correlated.

This dissertation joins previous conversations in technology studies that discuss the interrelationships between the biological and the computational (Manning, 2009; Thacker, 2004) and extends these discussions to include self-tracking practices, the implications of personal data collection and big data mining to subjectification. I join more recently interdisciplinary approaches to pervasive computing, the Internet of Things and big data mining that have investigated issues of big data divide (Andrejevic, 2014), surveillance (Andrejevic & Gates, 2014; boyd, 2012; Haggerty & Ericson, 2000; Riley, 2014) and data epistemology (Gitelman, 2013; Van Djick, 2014).

This dissertation also answers to Rob Kitchin's (2014) call for research approaches to data mining practices that goes beyond the identification of data patterns and correlation in social networks, and instead discuss the processes of formation and reproduction of these patterns, their social and political consequences. Secondarily, this dissertation also fills in a gap in pervasive computing research to encompass a multidisciplinary approach that does not only focus on the functionality of computing applications but also on the material affordances and the power forces of the practices they render.

To address these gaps, I examine the implications of self-tracking, sustained by a digital episteme (Maddalena, 2014), at the micro-scale of the individual and the macro-scale of social politics. At a personal scale, self-tracking practices leads to the production of a sense of self that is bound to numeric measurement produced by sensors and mobiles applications. For example, the measuring of heart rate, glucose level, blood pressure values provide a "score" of your health condition, and thus define how healthy or unhealthy you are. At a global scale, the aggregation of personal data leads to data correlation for predictive models that are later translated into norms and regulations and in evaluation of risk. In this latter example, correlated data will define the target values that define the numeric parameters of a healthy body, and possibly have an effect on health policy regulation and on health insurance coverage. Moreover, big data mining is comprehensive and might include sets other than physiological data, such as purchase history, credit score, background check…obtained through specific agencies that collect this data (i.e. banks), through disclosure on social media, and parsed out through specific algorithms. One danger of data correlation lies in the potential of its application for discriminatory practices (when social profiling based on correlated data is conflated with the truth). This might happen, for example, when data analytics is taken as the sole variable to define a profile of potential terrorist activity that produces a risk profile that is defined within specific ethnicities, thus expanding the assessed risk to an entire population. It can also be present in consumer profiling in what is recently being called "digital redlining." The term is an algorithmic actualization of the term "redlining" that was coined in the 1960's by John McKnight (Sagawa & Segal, 1999) to describe the practice of marking areas on a map where banks should not authorize loans. The issue was that the redlined neighborhoods were typically populated by racial minorities, and the bank policies further worsen their economic situation. Similarly, as the redlining of neighborhoods served to mark the undesirable consumers, algorithmic redlining through automated data correlation can serve as a proxy to reproduce ongoing biases and reinforce asymmetric purchase power and access to services. Data analytics might provide some insight to how individuals act, but it is limited in scope and context. During this dissertation, I address the pretense objectivity of data and argue for a critical understanding of data analytics as performative and embedded in a rhetorical materiality of modular numeric discretion.

This dissertation investigates how the use of pervasive computing technologies devises practices of self-making through the appropriation of sensors and data mining strategies. It also investigates how self-tracking practices turns the biological body into a site of physiological data as well as a territory built upon data correlation. And finally, I investigate how the use of pervasive technologies and big-data mining strategies produce networks of power by producing forms of knowledge through quantified data and negotiating data ownership, privacy and parameters to assess risk. I examine these questions by engaging with self-tracking and by observing the followers of the Quantified Self movement. I also examine these questions as a critical maker in the construction of an interactive installation that rearticulates the premise of objectivity assigned to digital data as a parameter for knowledge construction.

In the following section, I articulate the theoretical framework in which I approach the Internet of Things, the methodological approach and I provide a guide for the structure of this dissertation.

Theoretical framework

This dissertation describes the contemporary technological scenario in ways that take in consideration the complexity of social and technological relationships and the power dynamics that drive the shifts among these relationships. Thus, I was compelled to think about technologies and subject formations in terms of articulation among the physical arrangements of "matter, typically labeled technologies, and a range of contingently related practices, representations, experiences and affects" (Slack & Wise, 2005, p.128).

Deleuze and Guattari's image of the rhizome described in *A Thousand Plateaus* (1987) is a useful approach to the architecture of the Internet of Things. The figure of the rhizome synthesizes a post-Structuralist image of thought that has been often applied by digital media researchers to characterize open-ended and non-hierarchical networks. A rhizome replaces an arborescent structure, which is vertical, linear and hierarchical. A rhizome is horizontal and it extends itself horizontally, with no rigid structure or center. It grows from multiple connections it establishes of its formation that are only productive in relation to each other. A rhizome is composed by the connections among disparate entities, a map that has multiple entryways and that is not a dual representation, mimetic copy or tracing, of the world, but it is the world itself. I reiterate this association with the Internet of Things because, similarly to the rhizome, the IoT is founded upon an always-growing structure, as multiple nodes of connection expand the reach of the network. Consider the Internet of Things: multiple points of connection, devices, people, things, sensors, data running through, taking part, shaping and enlarging a network. Some nodes disconnect, others join, part of the infrastructure fails (cables get cut, wi-fi drops), other parts of the infrastructure take over (more optical fiber is laid out). Groups of people create online communities based on shared interest, multitudes of individuals massively populate the web with vines and snapchats. Open micro-controllers join and pull in short range wireless networks into the mix. Metadata is constantly being collected and creating traces of every action as it is tracing the network per se. The Internet of Things expands and contracts in articulated multi-dimensions, as different topological scales disconnect and rearrange. Thus, the multiplicity and the connectivity that prevails in the theoretical arguments of *A Thousand Plateaus* fits the heterogeneity, associative and innovative aspects of digital media applications.

Although the rhizome and the topological figure of the plateaus are useful to explain the co-constitutive dynamics between spatial, technological and human dimensions of the Internet of Things, they are not sufficient to describe the power dynamics at play. We must acknowledge that the dynamism of the rhizome is bound to the material affordances of technology (computing networks are bound to structured protocols in order to function) and to the power forces that shape the social use of technology (availability of infrastructure, policies of access, types of applications, etc.). As a theoretical model of network, the Internet of Things approximates of a rhizomatic structure. But as an actual technological network, it is forged in ways that privilege some connections over others, because the material and economic resources for the implementation of the required infrastructure are asymmetrical.[7]

Therefore, I produce a genealogical account (Foucault, 1985) of the Internet of Things that acknowledges the material and historical formation of the technologies, subjects and the social and political power that shape the IoT. Within the scope of new-materialist tradition to Philosophy, Humanities and Social Sciences, Michel Foucault's genealogy is a method that uncovers the relationships between power, knowledge and subjectification within historical periods. A genealogical analysis examines the conditions for the emergence of certain systems of beliefs, the parameters for truth and rationality, and how a society in a given historical time considers some things knowledge.

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[7] For example, North America has 87% of Internet penetration versus an average of 42% in the world. From http://www.internetworldstats.com/stats.htm

In *Discipline and Punish* (1978), for example, Foucault looks at the organization of the penal institution to describe how actions of punishment have been transformed into mechanisms of disciplinary surveillance and control over the individual body. The relation of discipline as a technique of power is intimately related to the moment in which the exercise of sovereign power weakens due to the questioning of its legitimacy—related to the crisis of feudalism and the rise of a productive economical subject (*burgeoisie*). Unlike the monarchical state which would justify its exercise of power through transcendental laws of divination to command over the population, the democratic state requires internalized mechanisms of surveillance and control to exercise its command, now justified also as a mechanism to provide the security of the population. This mechanics is materialized in the panoptic architecture of prisons which allows guards to observe the behavior of prisoners but doesn't reciprocate the privilege of visibility to the latter. Because prisoners cannot tell whether they are under surveillance or not, they are coerced to obey the rules faced with the possibility of punishment if caught in undisciplined behavior. The panoptic gaze over the incarcerated population, but that cannot be looked into the eye, is the materialization of the apparatus of disciplinarization and is present in other forms of technologies of power such as the church and the schools. Following this model, Foucault (1980) produced analysis of how power/knowledge dynamics produce complex power relations between institutional practices, bodies and systems of thought:

> Power must be analyzed as something which circulates, or rather as something which only functions in the form of a chain. It is never localized here or there, never in anybody's hands, never appropriated as a commodity or piece of wealth.

> Power is employed and exercised through a net-like organization. And not only do individuals circulate between its threads; they are always in the position of simultaneously undergoing and exercising this power. In other words, individuals are the vehicles of power, not its points of application (p. 98).

A traditional concept of power describes it as owned and exercised by an agent. In this framework, power is relational and productive (Foucault, 1985), and agency is distributed among relations where "one never commences; one never has a tabula rasa; one slips in, enters in the middle; one takes up or lays down rhythms" (Deleuze & Guatarri, 1987, p. 123). In the scenario of the Internet of Things, self-tracking practices are rendered through material potentialities and affordances, and are inscribed as modes of exercise of power. The materiality of the technology and the data infrastructure are paramount to how self-tracking takes practice. The analysis I develop to describe the dynamics at play in the IoT considers a co-constitutive relationship between the material infrastructure of digital technologies, the epistemic system of thought that sustain digital forms of knowledge, the subject formations that emerge from these relations and the economic and political forces that effect on issues of access and technology distribution. These relationships operate as folds (Deleuze, 1991) and break from the Euclidean static understanding of space and the Cartesian understanding of autonomous modern subject. I second Gilles Deleuze's approach to the creation of symbolic reality, our sense of selves and overall all practices of knowledge production as driven by an "affective capacity" laid out in "a common plane of immanence on which all bodies, all minds and all individuals are situated" (p. 122). The becoming-world is created through infinite folds and multilayered surfaces, that are weaved in and through time and space. In this sense, bodies, spaces and forms of knowledge are states of becoming, and are defined through their capacities for affecting or being affected, while they render the motions that animate their own becoming:

> In the first place, a body, however small it may be, is composed of an infinite number of particles; it is the relations of motion and rest, of speeds and slowness between particles, that define a body, the individuality of a body. Secondly, a body affects other bodies, or is affected by other bodies; it is this capacity for affecting and being affected that also defines a body in its individuality. (Deleuze, 1991, p. 123)

The power forces are multiple and work in and through space, social groups, different levels of data access and algorithmic intelligence, simultaneously producing forms of knowledge and shaping subjects of knowledge. In the next chapter I articulate how the infrastructure of access is critical to the understanding of the social uses of networked technologies, and identify the institutional agents in the industry, in the academia and in grassroots movements that shape the IoT.

In summary, I produce an analysis of the IoT as a material articulation of techno-social practices that transcode the analog physical world to digital data, thus implementing a digital way of experiencing reality and constructing our sense of selves. Through these lens, I perceive subjects and technologies as an assemblage of dynamic productive forces that brings to light how power relations are exercised, for example, through forms of data access, digital divide and governance of individuals.

Methodological approach

My approach to these questions draws from the new materialist tradition to Media and Cultural Studies which stresses the co-constitutive relationship between embodied individuals, culture, and the physical world around them. This tradition is articulated here through dialogues I established with authors who recover the dependency between embodiment and subjectivity (Farman, 2012; Haraway, 1991; Manning, 2006, 2009; Munster, 2006), the understanding of technologies as social artifacts and as material articulations of forms of knowledge (Fuller, 2005; Galloway, 2004; Galloway & Thacker, 2007; Rose, 2006), and reposition the subject as a process in becoming immersed in arrangements of power (Deleuze & Guattari,1987; Deleuze, 1991; Foucault, 1980; Latour 2002). Even though the term Internet of Things is often appropriated by the technology industry to brand research and development initiatives that deal with "smart" objects,[8] in this dissertation, I approach the technological infrastructure of the IoT beyond its devices. I present the Internet of Things through the material development of technologies, but I also acknowledge how it follows the social imaginary of ubiquitous computing, and how the participation of researchers, institutions and grassroots movements reshapes and actualizes the IoT in the actual technological landscape.

To approach the research issues mentioned previously I used mixed methods based on premises of Grounded Theory (Charmaz, 2006). Grounded Theory methods rely on empirical data constructed by observations, materials, events and experiences to develop theoretical analysis. My data consists of auto ethnographies of personal use of

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[8] See the R&D initiatives by Cisco at http://www.cisco.com/web/solutions/trends/iot/overview.html; by IBM at http://www.ibm.com/analytics/us/en/internet-of-things/, and by Microsoft at http://www.microsoft.com/en-us/server-cloud/internet-of-things/overview.aspx

self tracking technologies conducted during the entire research process, an observation of the Quantified Self online discussion forum between July and December of 2013, and a physical computing installation[9] entitled “Truth or Dare” (ToD) that was showcased in two art exhibits in 2013 and 2014.

In different periods of the investigation I conducted auto ethnographies and kept notes and memos of my personal experience with wearable technologies. The anecdote in this introductory chapter describes one situation of my experience at the clinical trial, which monitored my sleep quality through a wrist biofeedback sensor. I conducted another auto ethnography using the Misfit Shine, a fitness tracking wearable device (described in chapter 4). These ethnographies were conducted in different times of the research process—the clinical trial at Duke happened in the initial stage of the research in the Fall of 2012, and the use of the Misfit Shine fitness tracking happened in Fall of 2013— because as I progressed with the data gathering I recognized the need to complement the data set with primary accounts of use of the technologies. The conduction of the auto ethnographies in different stages allowed me to compare memos and notes from each ethnography with each other and concurrently with the other data sets I gathered in my observations of the Quantified Self forum and the “Truth or Dare” installation. This setup corroborated one of the key methodological guidelines of Grounded Theory, which is the constant comparison between data sets during all stages of analysis.

[9] The installation used using arduino, ioio and rapsberry pi platforms, biofeedback sensors, an Android smartphone and Twitter. I give more information about the installation on this chapter and a more detailed account of the setup in chapter 2.

The main reason I opted for ethnography as a component of my research methods is the prerogative to delve into the situational use of the technologies. This allowed me to gather rich data that provided me with multiple dimensions of the use of these technologies. By using the aforementioned devices, I became more aware of how my biological body interacts with and negotiates different levels of intimacy with technology, and how technology creates new knowledge of my personal biology, and consequently of my self. The choice of auto ethnographies for this study allowed me immerse and gain an insider's perspective of the reality at study while actively reflecting upon the events. From the data gathered during the ethnographies I was able to articulate my research questions and create interpretative renderings of the data set.

Based on the initial observations produced by the ethnographies, I developed the concept for the "Truth or Dare" installation, described earlier in this introduction. The construction of "ToD" allowed me to develop critical knowledge about wearable technologies while engaging with material production. According to Ratto (2012), critical making as a method bridges two modes of engagement that are frequently depicted as divorced. Critical thinking, often taken as a mental and intellectual process, and physical making, often described as goal oriented work, can be combined and generate innovative, critical hands-on experimentation with concepts and materials. The construction of the prototype and the assembling of the installation was a long process of non-linear progress. My technical skill set often fell behind my Social Science scholarly expertise. Even though the many trial and errors with the installation setup was a logistics challenge, it also presented itself as an opportunity to experiment with the technologies while voided of training bias, and to test the limits of the design concepts faced with the affordances of materials. The initial attempts to build the galvanic skin sensors—that collect the values of electric conductivity on the surface of the skin—exposed the challenge of interfacing organic and non-organic materials and translating physiological performance into electric response and digital values. The first readings were scattered and randomic and triggered a reflection about the material constitution of the flesh, the normalization of physiological performance translated into numeric ranges of health standards.

In addition to the installation, I observed the interactions that occurred in the Quantified Self website's forum between July and December of 2013. I kept records of all the interactions and based on Grounded Theory guidelines for textual analysis, and I examined the data to identify emerging categories.

Emerging categories and research questions

During my investigation, I wrote memos, collected images, recorded videos and kept field notes as referenced data of my experience using wearable technologies (the biofeedback sensor for the Duke hospital clinical trial and Misfit Shine, a wearable fitness tracking device), constructing the "Truth or Dare" experiment and observing the online discussions on the Quantified Self forum. The initial phase of my analysis comprehended selecting the most significant situations in the aforementioned experiences and describing *what is happening* in each situation. I assigned code-names that summarized the situation of each segment of data. Next, I sorted and organized each segment of data into most frequent occurrence and also mostly significant according to my initial research question. At this point, my main research question was tentatively expressed as "What happens when pervasive computing technologies are embedded into the biological body?” and my research interests guided me to look at changes in human subjectivity, in spatial practices and forms of power. The cross-comparison and grouping of the coded data brought forth the following emerging categories of analysis:

1. Self-making through pervasive computing technologies: The first category comprehends data segments that touch on the relationship between individuals and their biological bodies forged by data collected through self tracking devices. The data gathered demonstrates how the access to physiological performance’s digital data renders a data double of the self. The physiological data awareness reinvents how the user comprehends and interacts with her own body and prompts new practices of self-making. This category accrues evidence of shifts in the construction of human subjectivity when interfaced with pervasive self-tracking technologies.

2. Space-making and pervasive computing technologies: The second category comprehends data segments that touch on the interconnectedness of digital and biological bodies as networked social spaces. The extension of computing into bodies of living and non-living things and physical spaces create the possibility of mapping the internal space of the body as we map physical geographical spaces. This category concentrates on observations that refer to the body as a space to be mapped and connected to other already mapped spaces.

3. Pervasive computing technologies and power: The third category comprehends data segments that touch on how pervasive computing technologies rearticulate networks of power. In this category I concentrate accounts of technologies as tools for self governance—in ways to care for the self—and potentially to care for populations—as data can be potentially accessed by other users and institutions. Users manifested that the access to their physiological data creates a sense of empowerment over their lives and at the same time that it brings awareness about data breaches and invasion of privacy and intimacy. The sense of empowerment is also shared by makers who, given the access to open hardware and software, come up with new strategies to develop devices. Some makers and adopters of pervasive computing technologies accredit the DIY maker movement as the exploit to shift the power dynamics and handle control from large technology corporations and over to the user. Simultaneously, other data segments show evidence of critique to the open source sandbox model of technological development and frame it as an alternative business model that maintains similar power dynamics as the mainstream large corporation business model.

These are the emerging categories that demonstrated greater saturation in the data gathered and that more significantly related to the initial research questions. Other categories emerged in the initial analysis, however they did not relate to the research questions or did not represent sufficient saturation to justify their relevance. In the Quantified Self forum, for example, I noticed a large quantity of posts with requests to participate in surveys for independent, private, and academic research. This category, while possibly relevant to Rhetoric of Science for example, was not included in this study as it did not relate to the issues of interest to this study. In this perspective, the aforementioned categories are not necessarily the only possible cluster of evidence from the data gathered. They reflect my research interests, theoretical formation and scholarly background. Also, I must reiterate that they are not clearly bounded and certainly are not self-sufficient. All three categories are interrelated and observations that are discussed in one category may also relate to a different category.

In Grounded Theory (Charmaz, 2006), the data set guides the researcher through the definition of the methodology as well as the theoretical framework. My personal research interests and scholarly background led me to a tentative research question that pointed to the relationships between the use of pervasive computing technologies and human subjectivity, spatial practices, and power. After the initial analysis of the data set, the research questions and the theoretical frameworks were refined. Similarly, as the emerging categories are interrelated and traverse one another, the research questions are also founded upon these logics of articulation. This dissertation addresses the following research questions:

Research Question 1 (Pervasive Computing and Space): How are embodied spaces produced through the appropriation of pervasive computing technologies?

Research Question 2 (Pervasive Computing and Self): How does the use of Pervasive Computing technologies devise practices of self-making?

Research Question 3 (Pervasive Computing and Power): How does the use of Pervasive Computing technologies produce networks of power?

Structure of dissertation

Wearable Computers, Internet of Things, Pervasive/Ubiquitous Computing. The names are many in the attempt to describe the current technological landscape where networked computing devices are embedded into architectural/physical space and bodies of living and non-living things. The next chapter delves into the historical and conceptual definitions that form the contemporary technological landscape of wearable computers, sensors and wireless networks. In this chapter I present the origins of early 1980s research in Ubiquitous Computing at Xerox PARC and the heritage of this research agenda in building the Internet of Things. I also discuss how the availability of open source micro-controllers and microprocessors and the emergence of the maker movement are important components to the advance of research regarding technology appropriation. I explain how Critical Making is structured as a research method for interdisciplinary research and specifically, in this dissertation, how I have taken this approach in the conduction of a critical making experiment.

Chapter two presents the narrative for conceptualization and the making process of “Truth or Dare.” I describe the steps of the construction phase, the challenges I encountered and the setup for the exhibits the installation took part of. I also introduce the critical reflections that were triggered during the making process.

Each one of the following chapters addresses one of the research questions mentioned in the previous section. In chapter three I address the first research question (How are embodied spaces produced through the appropriation of pervasive computing technologies?). I explain how digital data and the dynamics of data mining produce multi-scalar spatial dimensions in the Internet of Things. I demonstrate how the materiality of digital data and practices of data mining produce forms of knowledge in scalable dimensions: from the micro dimension of the self to the macro dimension of smart cities and social politics.

In chapter four, I reiterate the pervasiveness of a digital episteme (Maddalena, 2014) to address the second of my three research questions: how does the use of Pervasive Computing technologies devise practices of self making? To answer, I describe self-tracking experiments reported in the Quantified Self forum in which the body and the mind are the sites of investigation, and the situations that occurred during the exhibits of the ToD installation, in which participants constructed their identities as truth tellers or liars. I discuss these practices of self-making as a form of self governance (Foucault, 1997, 2003) enacted through the material organization of digital technologies. I position this discussion in the wider context in which digital data and demonstrate how the making of the self is grounded on the digital episteme (Maddalena, 2014). I approach digital metering from a socio-historical perspective to reinforce the relational dynamics in which the self is simultaneously a product and the producer of the assemblage she is part of.

In chapter five, I address the last of my research questions: how does the use of Pervasive Computing technologies produce networks of power? I discuss implications of the previously discussed self-making practices and spatial practices as forms of power. I argue that the self-tracking, as a tool for self governance—in ways to care for the self—and potentially to care for populations (Foucault, 1997, 2003)—can also produce practices of surveillance. I describe the Internet of Things as a sociotechnical assemblage that operates under the aegis of control (Deleuze, 1997), as a surveillant assemblage that demands the negotiation of new boundaries for privacy and intimacy. Self-trackers state that the access to their physiological data creates a sense of empowerment over their lives and at the same time it brings awareness about risk of data breaches and invasion of privacy. The sense of empowerment is also shared by makers who given the access to open hardware and software come up with new strategies to develop devices. Simultaneously, the open source sandbox model of technological development of makerspaces is also criticized when independent initiatives are sponsored by government funding and adopt an alternative business model that maintains similar power dynamics as the mainstream large corporation business model. I also present other emerging forms of power through discourses in critical appropriation of technology, often present among makers and sometimes among users of the Quantified Self forum.

I conclude the dissertation by presenting a reflection on my findings and indicating the main areas of contribution to the fields this study proposed to relate to. I also point the limitations of the study and indicate potential unfoldings for future research.

Contributions of this study

This dissertation contributes to scholarship in the field of Digital Media, and Cultural Studies in three main aspects.

As I argued in the beginning of this introduction, there is a growing interest in pervasive computing technologies and self-tracking practices. Even though the number of publications is still limited, the growth of the market of wearable devices and the number of research projects in development demonstrates the relevance of the topic. The first contribution of this dissertation is a gesture towards the expansion of studies regarding self-tracking practices, which, due to their novelty, are still under researched. Because the appropriation of wearables and sensors is fairly recent, and the Internet of Things is in ongoing implementation, studies about the sociotechnical implications of these technologies have only recently started to emerge.

The second contribution speaks of the interdisciplinary framework adopted to study the IoT and practices of self-tracking. Previous research approaches the Internet of Things as an extension of mobile media (Dourish and Bell, 2011; Goggin, 2011), and study self-tracking through life-logging ethnographic accounts (Watson, 2013) and as a tool for health-management (Lupton, 2015). My approach to this study reconciles a genealogical survey of the Internet of Things (narrated in the next chapter), while attentive to the material arrangement of data and its epistemic action. The approach I develop acknowledges self-tracking practices as part of a sociotechnical arrangement and characterizes the dynamics between the analog/physical and digital/numeric worlds as a creative and co-constitutive weaving. Self-tracking is discussed in this dissertation as an action-to-knowledge about the self created through numeric, discrete and modular data units. Through this perspective, the role of the digital interface is described as a complex and modular embodiment within physical realities, differently from a functional approach to technologies that approach interfaces as a binary filter of the "natural" world (Howard, 2011). Through this framework I discuss technology appropriation as a procedural material articulation of discourses, social practices, and actions. I perceive subjects, technologies and spaces as an assemblage of dynamic productive forces that brings to light how power relations are exercised, for example, through forms of data access, digital divide, governance of individual's and populations' physiologies.

The third contribution brought by this dissertation is the application of critical making (Ratto, 2012) as a research method within a theoretical framework that combines a genealogical approach to the Internet of Things with an epistemic lens to digital data. Critical making is a method developed by Matt Ratto (2012) to reconcile the gaps that Critical Theory (specifically the Frankfurt School) left regarding material production as a means of critical reflection. Through the conceptualization and construction of the "Truth or Dare" installation, I explore technology appropriation in theoretical and physical dimensions for scientific inquiry. As Katherine Hayles (2012) reminds us practice-based research is relatively new to the Humanities:

> The work of making—producing something that requires long hours, intense thought, and considerable technical skill—has significant implications that go beyond the crafting of words. Involved are embodied interactions with digital technologies, frequent testing of code and other functionalities that results in reworking and correcting, and dynamic, ongoing discussions with collaborators to get it right (p.19).

Critical making comprehends the overall process of material engagement with technologies, that is reflexive and informative about how the world is while at the same it deconstructs and opens up new articulations for how we relate to technology and society. The purpose of the "Truth or Dare" installation was also to explore the possibilities of experimentation beyond the modern episteme of the scientific method, in which the experiment serves as an instrument of data collection to extract evidence from the observed reality to either support or deny a hypothesis. With ToD, I appropriated of digital technologies and utilized algorithmic analysis as a creative method to explore the epistemological underpinnings that produce algorithmic knowledge.

The production of an interactive installation also aims to call attention to the possibilities of multimodal composition in digital media research. The adoption of another mode of composition besides text, which is typically the most common format for cultural and critical theory studies, enriches media technologies research and fosters scientific innovation. By engaging with digital media as a constructive activity, I engage with the material processes and explore the conceptual limitations that shape the use of a media technology. I explore the rhetorical agency I have on the means of symbolic and material production of a technology, and develop a critical perspective over the relationships between technology development and appropriation.

ToD is motivated by a genealogical research of self-tracking technologies and for that, takes into consideration how the biological body is inscribed in a power-knowledge dynamics of digital self-tracking organized as a biopolitical practice of self-governance (Foucault, 1997, 2003).

In this sense, this dissertation contributes to the field of Digital Humanities and the new-materialist approaches to Cultural Studies by developing further critical making as a method that can overlap social-political perspectives with discursive and material analysis. Through this dissertation, I also argue for further interdisciplinary collaboration among the fields of Humanities, Social Sciences and Computer Science to nurture further debates about the social, ethical and political implications of new media technologies, specially regarding data mining practices and physiological information.

CHAPTER ONE

Internet of Things: building a landscape of technological folds

If you are ever invited to go to Bill Gates' house,[10] you will have to go through doors operated by biometric locks and you will be given a microchip pin to wear. This pin will pinpoint your exact location in the house and relate information to sensors embedded in to the architecture of the house to adjust the temperature of the room according to your preferences, to turn lights and devices on and off as you move across the house. If you are a particular fan of a painting, the image will follow you around the house being cast on the in-numerous screens installed on the house. When Bill Gates finished the construction of his smart home in the mid-nineties, the novelty of home automation through lasers, networked sensors and voice activation materialized the wizardry of the near future portrayed by movies such as *Back to the Future (1989*) and the TV series *Star Trek* (1966-1969). Twenty or so years after, the automation of the domestic space is increasingly familiar, as trivial objects and even our own bodies are interweaved with networked digital infrastructure. Off-the shelf home automation systems controlled remotely through smartphones, wearable health tracking devices and DIY kits that allow you to customize sensors and responses to particular needs are available on the market at a more accessible price point that Bill Gates was billed for in the 1990s. The contemporary technological landscape composed by networked sensors and embedded devices in physical spaces and bodies is defined as the Internet of Things. It is established through heterogeneous networks that include the internet but is not limited to it. It is composed by the interaction between users and machines, and machines

[10] As described in Gates' biography *Road Ahead,* published in 1995 by High Bridge Company.

and machines, and includes multiple digital devices and diverse digital infrastructures, such as mobile media, wearable sensors, location-aware technologies, geomapping systems, and RFID tags. The IoT is a mark of pervasive and ubiquitous computing, as it moves towards an (but never quite there) immediate ubiquity of computing devices and digital networks.

The term Internet of Things was coined by Kevin Ashton (1999) in a lecture given at Procter&Gamble about uses of RFID (Radio Frequency Identification) as an efficient cost-effective system for the identification of goods in the company's supply chain. More than identifying goods (as a regular bar code would), the use of sensors that read the RFID tags allowed for real-time monitoring of the physical state of the goods and location. These interactions between sensors and tags provided the network with information that further enhanced the supply chain efficiency, as it feeds back integrated information processing. Since 1999, RFID technology has been implemented in various applications such as logistics and transportation (supply chains, traffic control and electronic toll collection); fields of research (environmental sciences, to track species migration patterns and population sizes); marketing (interactive and personal advertising); and government services (new generation of e-passports). After Ashton's lecture, the term Internet of Things quickly caught on to name information networks that rely on sensors (not limited to RFID) in conjunction with physical things to feed data into the network and while doing that, re-empower the network's processing capacity. Internet of Things is fundamentally marked by a shift in how networked computing interacts with the physical world through sensing to process intelligent responses. The becoming of the Internet of Things is then funded upon the creation of "smart things" (as things are empowered with connectivity capacities), and evolves with the development of more seamless hardware, such as wearable computing devices—i.e., Steve Mann's WearCam and Google Glass—and nanotechnologies—e.g, silk silicon embeddable electronics and biofeedback sensors.

In this chapter I provide a historical perspective and a conceptual survey of the contemporary technological landscape of the Internet of Things. I present a possible historical account[11] of the Internet of Things as emerging from three overlapping initiatives: the research and development initiatives in ubicomp and pervasive computing at companies such as Xerox and IBM, the research agenda at academic institutions such as MIT group *Bits and Atoms*, and grassroots tinkering movements with physical computing prototyping in hacklabs, hacker and makerspaces. I begin from the historical context in which ubiquitous computing (ubicomp) research started at the Xerox PARC Laboratory in the 1980s. I argue that the concept of the Internet of Things derives from an ubiquitous computing imaginary deeply rooted in Mark Weiser's vision of the computer of the 21st century (Weiser, 1991). At the same time, it diverts from it, as the Internet of Things takes shape in a technological scenario where the material affordances of the infrastructure often prevails over a design of *calm computing* (Weiser & Brown, 1995). From there, I trace a conceptual map of terms that emerged from ubicomp, such as pervasive computing, physical computing, tangible media, and everyware, and their attempts to elucidate the social and technological transformations at work. Then I present the rise of the maker movement, hacker, and makerspaces as events that produce the

[11] This account is limited to what pertains the participation of the actors cited and does not imply to be a totalizing narrative of the Internet of Things. It is also limited in terms of geographic and cultural context as the narrative I present covers the implementation of the Internet of Things in the northern hemisphere.

Internet of Things as also emerging from technological development and appropriation in self-organizing communities and through individual entrepreneurship. The current applications of the Internet of Things are marked by a heterogeneity of platforms and competing protocols—produced by established tech companies and emerging independent makers—and the enhancement of location-aware technologies and physiology mapping as directives for the modeling of complex intelligent systems. I argue that the transition between an initial and a later stage of the Internet of Things is prompted by a set of three main shifts. First, a material shift in size, as the miniaturization of computing technologies reaches micro and nano levels which allows computing technologies to be embedded into physical spaces, bodies, and things. Second, a shift in accessibility, with greater affordability of digital hardware and expansion of internet infrastructure. And lastly, a shift in distribution, as open access microprocessors, micro-controllers and sensors are popularized, and DIY strategies take shape in movements such as communities of makers and hackerspaces. In this chapter I also demonstrate how the rise of the maker movement contributes to the establishment of innovative forms of technology appropriation and therefore stimulates experimentation. I conclude this chapter by addressing critical making as an emblematic research method for social studies of technology.

The role of social imaginaries and infrastructures

While the term Internet of Things originally derives from a technical oriented discussion of sensors, the concept of the Internet of Things is tied into the history of the electronic computing and information networks, as well as in the social imaginary of ubiquitous computing. Even before the Internet of Things was widespread, applications of computer automation, connectivity, sensor technologies and nanotechnologies populated the cultural imaginary. Some examples in literature and cinema are the smart household where the McFly family lives in the *Back to the Future* (1989) franchise which includes smart glasses and smart fridges; the variety of handheld devices in the *Star Trek* (1966-1969) series that allow for sensing, scanning and processing data; voice activated artificial intelligence such as the character HAL 9000 from *2001: A Space Odyssey* (1968); the tele-screens that allow for ubiquitous communication and surveillance in George Orwell's novel *1984* (1949); cyber warfare as described in *WarGames* (1983); and the ubiquitous network of sensors that characterize the urban landscape in *Minority Report* (2002).

The construction of social imaginaries around the Internet of Things (and the desire for ubiquitous communication) is important because the development of new infrastructures of information is deeply entrenched into fictional fabrications of social imaginaries. Imaginary and technological infrastructures feed into each other acting on a desire to relate to a technological scenario and eventually disrupt into the emergence of new technologies.[12] Hence, looking at changes in the infrastructure of access is critical to the understanding of the social uses of networked technologies, especially when the changes include expanding the network reach to embed its capacities in infrastructure that would not traditionally be informationalized. It is important to think of infrastructure in terms of material and discursive aspects as they are built to fit predesigned functions as much as their use is shaped around their material affordances.

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[12] For a detailed account on the interaction between imaginary and consumption, production and shaping of new technologies, see Goggin's (2014) analysis of Taylor's (2004) concept of "social imaginary" applied to adoptions and uses of mobile internet.

Susan Leigh Star (1999), in her seminal work on ethnography of infrastructure, calls for an ecological approach to infrastructure in ways that take the relational aspect between infrastructure and human actions into consideration. Underneath singular—and potentially *boring*—aspects of infrastructure, lie narratives that are established within the groups that shape and make use of the infrastructure. In other words, there is a sense of embodiment of identity that is built in interaction with the infrastructure. For example, for an architect, a set of stairs is a component of a structure design and engineering project, while for person in a wheelchair, a set of stairs is an obstacle. Infrastructure is not a *thing* bare of meaning, nor a void stable artifact; it is in fact fundamentally relational as it becomes infrastructure in relation to specific practices of use.

Infrastructures change in time and human action and human identity shifts in interaction with infrastructures of technologies.[13] Harold Innis' (1951/2008) study of time-biased and space-biased media in relationship to their materiality show evidence of how the rise and fall of empires are related to their infrastructure of communication. Time-biased communication includes clay, parchment, and stone. They are typical of tribal and oral societies, they are more stable and reinforce local values of community and tradition. Space-based communication is notorious for more ephemeral materials such as print, radio and television. It privileges a more rational and non-personal way of thinking (not necessarily tied to tradition) that favors extending control over geographic space. Innis' analysis of the fur trade in Canada demonstrates the contrasts between a space-biased civilization (Europeans) and a time-based society (Native Indigenous). According to Innis, media (as infrastructure of communication) is biased towards forms

[13] Kathleen Oswald, in her dissertation entitled "Smarter, Better, Faster, Stronger: The Informationalized Infrastructure Ideal," presents a detailed account of studies of infrastructure in Cultural Studies.

of social organization, identity and exercise of power. It is thus essential to the understanding to the formation of societies.

More recently, Manuel Castells (2010), in *The Rise of Network Society*, indicates how networked infrastructures reshape economic, political, cultural and social relationships. The rise of information networks has impacted the perception of space (as simultaneous communication does not require physical proximity) and time (immediate communication disrupts chronological time and brings a sense of a continuous present). Both Innis and Castells provide evidence of Star's argument that infrastructures are not innocuous elements in the construction of social arrangements. They are, in fact, components of a larger social ecology that is constantly redefined while appropriating current and inventing new uses of infrastructure.

Hereof, I trace the concept of Internet of Things based on an understanding of infrastructures as an active actor in the forms of technological appropriation. The narrative I present is based on historical and anecdotal evidence and an analysis of the social and technological imaginaries it emerges from.

The heritage of ubicomp research

According to Weiser (1991), the history of computing is divided in three paradigms exclusively defined by the computing hardware at use. The first paradigm is marked by mainframes, followed by personal computing and lastly by ubiquitous computing. The history of the appropriation of networked technologies—which includes the internet and other forms of digital networks—is tightly bound to the history of hardware and network development but *not limited* to it. Here I present an account of the social appropriations of networked technologies that turned out in the Internet of Things.

The initial setup of the internet, as ARPANET, consisted of an experimental military network accessed from twelve fixed sites. It dates back to the late 1960s, early 1970s and goes until 1990 when the ARPANET was shut down. In 1987 the ARPANET went through a transition as a strictly military to a civil network and was named NSFNET (National Science Foundation Network) where universities and researchers were the majority of users (Abbate, 2000). The infrastructures of access were mainframes and desktops computers located in the universities and government buildings. Research and governmental institutions controlled the flows of information within the internet. For that reason, the use of the internet is also tethered to institutional purposes, such as research collaborations and governmental administrative processing. The rigidity of use and the restrictive points of access to the internet (bound to institutional fixed sites) is conceptually distant to the technological imaginary that nurtured the concept of ubiquitous computing and the Internet of Things.

The first discussions about the feasibility of a technological landscape remotely similar to the Internet of Things date back to the late 1980s when the first web page went online.[14] As the civil adoption of the internet expanded, Mark Weiser (1991) predicted possible uses of the internet and other computer networks beyond institutional uses. He also predicted forms of user access to the internet beyond tethered desktop computers and machine-to-machine communication protocols for automated data processing, regardless of user input.

His vision of the "Computer of the 21st century" (Weiser, 1991) described a network architecture accessed from multiple panels of various sizes and capacities

[14] See History of the World Wide Web at http://webfoundation.org/about/vision/history-of-the-web/. Accessed in October 2014.

occupying heterogeneous networks with distributed connectivity. Weiser's vision resulted from the applied research developed at the Xerox Palo Alto Research Center (Xerox PARC) which team had (un)intentionally started a beta generation of smart objects.[15] Between 1985 and 1990, a group of researchers at that office developed an interface to the office's Coke vending machine to solve what they called the "warm coke" problem. In both cases, a hardware interface was instrumented with a terminal room that put the machine online and allowed people to handle status requests from their desktop computers and consult whether the machine was full, and if the drinks were warm or cold. Running the program online saved time going to the vending machine when the inventory was zeroed or when available drinks were at a non-desired temperature. Similar initiatives also happened outside of Xerox PARC. In 1989, John Romkey and Simon Hackett presented the "Internet Toaster," the first electrical object to be controlled via TCP/IP at the 1989 Interop Conference, an annual trade fair for information technology.[16] But it was Weiser's team effort of developing hardware and documenting progress reports that set a foundational stone to the becoming of ubiquitous computing (ubicomp).

Weiser's team (Weiser, Gold & Brown, 1999) proposed human-computer interfaces (HCI) that are more focused on the "human reality" side of the process, in which the computing capacities adapt to the situational uses of the technology. The focus of the Computer Science Laboratory at Xerox PARC turns to the development of ubiquitous computing hardware where the twenty first century personal computer was envisioned very differently from the then current individual use, complex operation,

[15] The email thread that recounts the trajectory of the smart coke machine is available at http://goo.gl/MYUgLb.

[16] http://www.technologyreview.com/article/400889/internet-on-a-chip/. Accessed in October 2014.

black box, desktop tethered machine. Their approach was more focused on building computing environments where the computing processing and connectivity was shared among the devices, rather than on the development of one super desktop machine with outstanding hardware capacities. Weiser's conjecture described a multiplicity of devices embedded into the physical environment that did not require extensive technology literacy to operate. These devices would act as access panels to a shared network, and while networked computing is inherently everywhere, human-computer interaction would become natural and seamless to the point of vanishing into the background. For a computing environment to be truly ubiquitous, Weiser argued that the following criteria had to be met: (1) computing processing capacities must be embedded into ordinary physical objects, not only on desktop screen based machines. The computing hardware must be of minimal size and unnoticeable to the user. (2) These physical objects have their ordinary uses augmented with computing services, they have easy to operate interfaces that are seamless to the user. (3) The ubiquity of computing services relies in the shared connectivity between devices, applications and users and is not centered in one device. The omnipresent availability of interconnected computing processing is what characterizes ubicomp. To summarize, his vision of ubiquitous computing environments would be realized through a multiplicity of terminals in different sizes and capacities, such as tabs, pads and scrapbooks. They would be embedded and networked in ordinary objects, so the sensation of transparency would become within the social practices and use of the technology.

Weiser considered that the challenges for the implementation of this reality were mostly in the development of affordable hardware, distributed connectivity and software protocols that enabled the setup of mobile interconnected networks, established communication among heterogeneous applications, and processed location information. In this sense, he argues that the impact of personal computers in the history of computation is misplaced. The paradigm of the desktop computer is one transitional step towards truly personal computing capacities. As portable as they might become, they are still a transitional format towards more transparent and ubiquitous computing environments.

With this ubicomp vision as a set goal, Weiser's team focused on the development of visual screen-based, mobile hardware, radio frequency and infrared networks. The three major products that resulted of this research were the LiveBoard, the book-sized ParcPad and the palm-sized ParcTab (Weiser, Gold & Brown, 1999). The LiveBoard was a wall-size rear projection screen accompanied by a wall-display program interface that included remote collaborative drawing and note-taking software. While the LiveBoard was connected to the network in a more traditional way (it required a human to start the remote interaction), the ParcPad, a screen-based pad that used a pen computing interface, used a "near-field radio system" that warranted constant connectivity to the network. This feature allowed the ParcPad to be always "listening and speaking" to other devices also connected to the network. The ParcTab also had an important network capacity based on infrared technology that allowed it to communicate with other devices and applications, such as the LiveBoard. The ParcTab functionalities included email, note taking, calendar, a sketchpad and a pager.

The devices developed by the Xerox PARC team were the first mobile gadgets that incorporated multimedia functionalities with remote interaction activated by wireless networks. They are evidence of a shifting paradigm in personal computing that geared towards individual mobile devices of continuously decreasing size and increasing data processing capacity. The ActiveBadge Project conducted at the Olivetti Research Lab is another example in the deployment of ubiquitous computing. It consisted of an indoor positioning system that used wearable badges and networked sensors to determine the location of the user in a facility. The ActiveBadge addressed a real problem in the work environment in locating people with the purpose of routing calls (Davies and Gellersen, 2002).

Up to this point most of the applications focused on the work environment. But in the early 1990s, with the development of faster personal desktop computers, graphic user interfaces, dial up access and later broadband internet in the 2000s, a non-institutional network emerged where social communities, forums and personal communication prevailed.

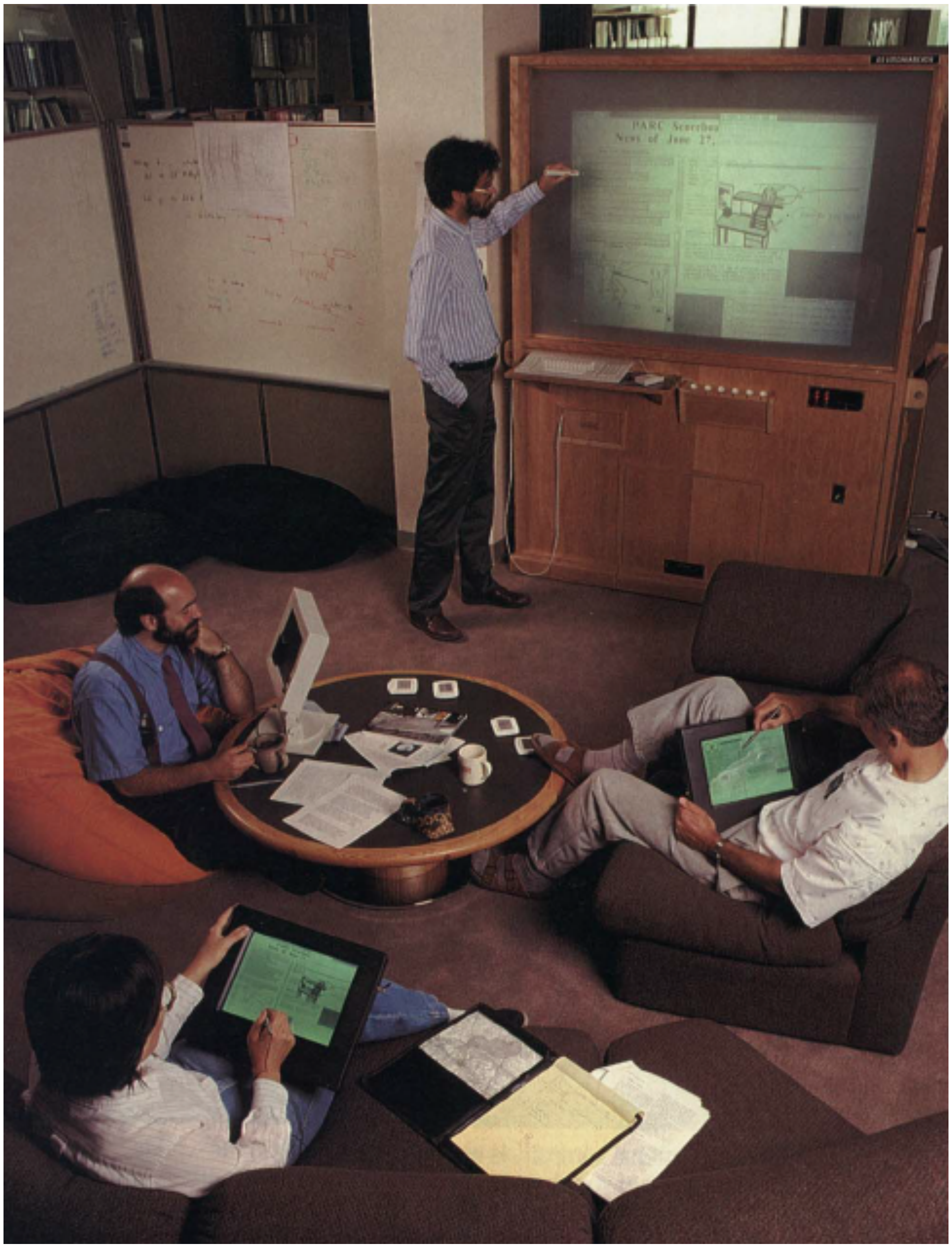

Figure 1: Early ubicomp hardwares developed at the Xerox PARC Laboratory. This photo was originally published in the article "The Computer of the 21st Century" by Mark Weiser (1991), Scientific American 265, 3, 66-75.

The development of mobile infrastructures of access pushed for the mobile internet, added with different network capabilities such as bluetooth and RFID, and contributed for a greater distribution of points of access to diverse networks across physical space. With the emergence of mobile screen-based devices, such as tablets and smartphones, and the availability of internet access expanded to cellular networks, the internet was made available on the go. The internet not only became personal, but also became untethered to a wired device.

Moore's Law has been describing this trend of miniaturization for more than 50 years now as the development of microprocessor performance still increases exponentially in relation to production cost. Moore's Law is a predictive model of technological development by Gordon Moore, co-founder of Intel, and was published in 1965 when based on his observations he conjectured that the number of transistors in a CPU doubles in every 18 months. This means that in every 18 months, researchers and industry are capable of delivering smaller and faster microprocessors—partially due to verified historical trend but also motivated by the foreseen schedule. But what the last 25 years in the history of computing technologies also have demonstrated is that Moore's Law can be extended[17] to other parameters such as internal storage and network speed. One consequence of that is the abundance of mobile devices such as tablets, smartphones, and pads among other networked objects that populate our surroundings. Xerox PARC's first tablets were the primitive version of the in-numerous mobile devices that populate our daily lives and assist us in handling our routines, serve as sources for entertainment, tools for documenting, interfacing social relationships and navigating physical space.

Concurrently, Paul Saffo (1997) interprets the Internet of Things as tied to the shift in computing development towards physical applications and the implementation of cheap, ubiquitous and high-performance sensors. In his 1997 article, "Sensors, the next

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[17] Not necessarily in an exponential increase, but still in an indirect relation.

wave of infotech revolution," Saffo argues that during the 1980s the key enabling technology of computing was the microprocessor. The development goal for computing technology was increasing processing capacity in individual machines. In the early 1990s, laser technology displaced the centrality of the microprocessor in computing and shifted the emphasis from processing capacity to access, as laser technology enabled connectivity between different media (i.e., high volume of storage in CD-ROM and DVD, high speed and large bandwidth with optical fiber). In consequence, computing devices changed in functions, from stand-alone devices defined by what they processed to networked devices defined by what they connected us to. In the late 1990s, high-performance sensors embedded in computing technologies and other non-computational objects replaced laser technology to interface interactions between electronic and digital devices and the physical world. Saffo (1997) preconizes the impact of this shift. Among his predictions, I want to call attention to two aspects. First, that the deployment of cheap input/output (I/O) computing devices would impact technology manufacturing and advance the creation of "smart" objects (as exemplified earlier in this text). And second, that arrays of sensors and actuators inserted into physical objects and spaces would bridge "the digital universe of our creation and the pre-existing physical analog universe" (Saffo, 1997).

Now we are faced with diminutive sensing technologies of access to the internet that allow the network to be extended to a series of devices and objects that interact among themselves and with end users. Digital information and processing capacities are increasingly intertwined in our everyday lives, from smartphone apps that use geolocation to crowdsourcing road mapping and *outsmart traffic* such as Waze;[18] to smart appliances such as Nest,[19] the smart thermostat that "learns" your schedule, programs itself and can be controlled from a smartphone; and transdermal bio sensors that measure the user's glucose levels and share the data wirelessly.[20]

We now know for a fact that advances in microelectronics granted the decrease of hardware size and allowed for greater availability of affordable components. Furthermore, the availability of affordable, open access micro-controllers, such as the arduino, encouraged communities of amateurs to develop prototypes of smart objects.[21] Saffo's (1997) predictions were realized in a way that welcomed physical computing experiments that were key to the deployment of the Internet of Things.

Physical computing is an important component of the Internet of Things' infrastructure, as it is based on active and interactive physical systems built upon software and hardware that can sense and respond to the physical world. It is established on the interaction between the physical sensory world and the computing capacities that translate that sensory reality into computable data. Physical computing projects create systems that collect sensorial inputs from the physical world, process that input according to parameters in a program and in result feedbacks outputs. Considering that the paradigm of the personal computer confined the network to the cyberspace accessed through a desktop and privileged virtual worlds created on screen based simulations,

[18] See Waze. Retrieved from https://www.waze.com/.
[19] See Nest, the next generation thermostat. Retrieved from https://nest.com.
[20] See Needle-free monitoring and drug delivery initiatives from Echo Therapeutics. Retrieved from http://www.echotx.com/.
[21] In chapter 4 I discuss further how the emergence of maker and hackerspaces and the Do-It-Yourself approach to physical computing challenged the formal power networks that traditionally dictate the access to state of the art technology.

physical computing brings the physical world back into the digital infrastructure by moving the interaction space out to the physical environment (Weiser, 1991).

The research at the Center for Bits and Atoms[22] at MIT, led by Neil Gershenfeld, explores this very connection between computer science and physical science. The projects under development are based on the same premise of the Internet of Things, named as “Internet-0,” a concept known as inter-device internetworking. Gershenfeld and Vasseur (2014) tell that around 1995 the research group had started experimenting with physical computing to extend the internet into things. While the name “Internet2” was being used to describe the even higher speed internet, they decided to name the short range sensor networks they were working on as “Internet-0.” The main goal of Internet-0 was to embed IP connectivity into the smallest objects (i.e., a lightbulb) in ways that the connectivity was self-contained in the physicality of the object. The development of micro-controllers[23] turned this possibility into reality.

It is key to the implementation of physical computing that the industry provided sensors, microprocessors and micro-controllers that were small in size so they could be embedded in other objects or in the physical space, and powerful enough, so they could read inputs, process data and feedback actions based on programmed scripts. Intel, one of the industry leaders in microprocessors, expects[24] that by 2020, 50 billion devices will be connected to the internet, an average of six devices per person (if the distribution were uniform). According to Panagis Papadimatos (2005), less than a quarter of all chips produced by Intel is put into desktop or laptop computer motherboards. The majority is

[22] http://cba.mit.edu/. Retrieved in April 2015.
[23] Microcontrollers are small circuit boards that contain a small processor that computes inputs collected through digital and analog pins and based on a predefined program, reports outputs.
[24] Retrieved from http://newsroom.intel.com/docs/DOC-5224#infographics1

embedded into analogue physical objects that would not originally function based on computing technologies (i.e., smart thermostat systems, such as Nest).

The development of smart products aims straight at calm computing, manifested by their clean design, simple touch based or voice operated interfaces, plug and play installation and automatic syncing with other appliances and accounts. And each day a new *smart object* is available on the market. The industry is investing robustly to reassure that if you are not there yet, we will be there soon. A business report from Pike Research shows that the revenue for smart appliances industry should skyrocket from $613 million in 2013 to $34 billion by 2020.[25] Globally, about $25 billion will be spent on smart grid initiatives by 2018. According to Intel, the home automation market should jump from $16,9 billion in 2013 to $35.6 billion in 2016. [26]

With that, the digital infrastructure becomes more distributed and mobile. In consequence, it becomes more pervasive to physical environments. Pervasive and ubiquitous are terms often used interchangeably to describe the contemporary technological landscape. The application of the term differs according to the disciplinary origin of the research group and the affiliation with the industry. They are also historically situated and express different expectations about computing technologies. The origin of ubicomp is historically defined within the 1980s research agenda of *calm computing* at Xerox PARC. Ubicomp's main goal is to develop a new paradigm of interactive computing that moves computers into the background to the point that they are imperceptible. The term *ubiquitous* implies that computing capacities will be

[25] Retrieved from http://www.businesswire.com/news/home/20130206005196/en/Smart-Appliance-Market-Reach-35-Billion-Annually#.VF76k_TF_E4
[26] Id.

available everywhere in the space, thoroughly integrated into everyday objects and activities, in ways that the computing processes are rendered invisible to the user. While still imperceptible, the processing capacity is universally distributed. Weiser's (1991) vision of ubicomp acts as a manifesto for the future of technology, as something yet to be achieved. As discussed previously, the promise of omnipresent access is argued by Weiser and Brown (1995) as a way to re-center the human in HCI design.

According to Hansmann et al. (2003), the term pervasive computing derives from the research agenda of ubicomp. However, while ubicomp is future-oriented and speculative, pervasive computing is focused on current applications that gradually become pervasive and might reach ubiquity. It implies widespread, distributed computing access and can be understood as a measure or a transition stage towards what might become ubiquitous. The use of handhelds and mobile media are examples of pervasive access to networked computing capacities, considering that through it one can provide and engage with network connections. While ubiquitous computing is vanishing into the background, pervasive computing deals with "a numerous, casually accessible, often invisible computing devices, frequently mobile or imbedded in the environment, connected to an increasingly ubiquitous network structure" (NIST Pervasive computing conference, 2000).[27]

Pervasive computing's research agenda is designed by a wide group of key actors in the academia and in the industry and positions itself as a feasible alternative to the imaginary of ubiquitous computing. According to M. Satyanarayanan (2001), former chief editor of the *Pervasive Computing Journal*, the implementation of ubicomp fell

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[27] NIST Pervasive computing conference 2000. Retrieved from *http://www.nist.gov/pc2000/*

short due to the unavailability of the required technology. So, even though research in pervasive computing is driven by the vision of ubiquitous computing (and both terms are often used interchangeably), pervasive computing research diverges from ubicomp as the first takes in consideration the actual possibilities of current technology.

The scholarship in pervasive computing originates from two other areas of research dating back to the 1970s: Mobile computing and distributed systems (Satyanarayanan, 2001). Distributed systems provided a hefty conceptual framework involving personal computing and local area networks (LAN). Mobile computing presented solutions for communication protocols, unpredictability of network signal strength, battery life of devices and location-aware features that were essential to the implementation of pervasive computing. The actors that contribute to the area often publish at the *Pervasive Computing and Mobile Communication Journal, IBM Systems Journal,* and *Wireless Communications*. The cooperation among academia and industry is common, and often government grants are followed by private investments in university media labs and conference sponsorships. The biggest sponsors for research in this area are IBM (and their pervasive computing division), Microsoft, Hewlett Packard and Nokia. Unsurprisingly, the pervasive computing agenda is focused on the areas of expertise of the aforementioned industries and is more focused on the distribution of handheld and wearable computers, wireless networks and devices to sense and control appliances. It criticizes ubicomp's vision in the following points:

- Invisibility: Weiser's vision predicts the complete disappearance of the computing technology in the physical environment. User and computer are seamlessly integrated to the point that naturalizes the interaction with the machine almost at subconscious level. Pervasive computing acknowledges that in practice such design is not technically possible and potentially undesired. Satyanarayanan (2001) argues that "a modicum of anticipation may be essential to avoiding a large unpleasant surprise later, much as pain alerts a person to a potentially serious future problem in a normally unnoticed body part" (p.11).

- Hardware design: Weiser correctly predicted how the increase of processing power and storage capacities were central to the miniaturization of computers. However, the development of technologies such as GPS and RFID have increased the number of physical devices. Moreover, the establishment of the World Wide Web as a global network of services, and the emergence of smartphones as ways to access the web, turned the third era of computing to a different direction. Instead of vanishing with computing devices, they are instead multiplied and visibly scattered in physical environments. Smartphones are symbols of status and fashion and the aesthetics of the design is one of the driving forces of the mobile telephony market. Users customize their hardwares with cases and stickers; add water-proof, scratch guard protections to screens and keyboards. These are evidence of how attached users are to the hardware (Davies and Gellersen, 2002).

- Privacy issues: Weiser's (1991) concern of privacy issues is limited to the need to increase network security and protocols for data encryption as we are faced with more pervasive and ubiquitous computing networks. He calls attention to potential technical challenges to ensure that private data is not made available publicly and does not expand on how the new parameters for data sharing might bring implications for the understanding of privacy per se. The deployment of completely integrated computing networks (WWW, intranet, GPS, cameras in public and private spaces) as described in Weiser's article (Weiser, 1991) demands a long process of social negotiation and legal regulation (Davies and Gellersen, 2002) that touches on renegotiating parameters for privacy understood in its social and political dimension, beyond technical possibilities.

- Scalability of Networks: Many users experience tests were conducted with the tabs and pads developed at Xerox PARC. At the time, the ParcTab system was installed in a large office with 50 infrared cells and a community of more than 40 users (Davies and Gellersen, 2002). The usability for the work environment was immediately appealing. However, when 20 of these users gathered in a conference room and were required to share the same bandwidth, the network was unable to handle the requests. Pervasive computing research calls attention to the limitations of the network and also to the unequal allocation of bandwidth among devices.

Pervasive computing is characterized by a saturated computing and communication environment enabled by technologies that support mobility. Therefore, the research agenda of pervasive computing subsumes mobile computing and goes further. Pervasive computing pushes for dislocating internet access from one screen-based device (i.e., a smartphone) and spreading it everywhere through the *informationalization/digitization of the infrastructure,* that is, by embedding computing processing capacities to objects and physical spaces and integrating their use to the network. Smart spaces combine two types of infrastructures that had been disjoint until now: computing and architectural. As a result, spaces/objects become embedded with computing capabilities, including sensing and remote control. Nest, the smart thermostat mentioned earlier, is an example of a smart appliance that automatically adjusts the physical environment (regulates temperature) based on pre set configurations, sensor readings and artificial intelligence (the device self enhances based on analysis of past settings). At the same time it controls the physical space, its behavior is readjusted based on the environmental readings.

As research progresses and technology development confirms or diverts from the initial vision of ubiquitous computing, other terms emerge to better characterize the contemporary technological scenario.

Adam Greenfield (2006) proposes the term everyware in an attempt to reconcile the in-numerous research initiatives under the umbrella of pervasive and ubiquitous computing. He justifies the necessity for a new term due to the diversity of ubiquitous computing functionalities that do not seem to converge on one thread of homogeneous applications, much less to fulfill Weiser and Brown's (1995) ideal of calm technology. Everyware should be broad enough to characterize the heterogeneity of user interfaces as "a diverse ecology of devices and platforms," (Greenfield, 2006), as hardware and software are embedded into clothing, rooms, appliances, cars, and even our bodies, in unprecedented levels of access to information and control over our environment. In Greenfield's point of view, all these different manifestations of ubiquitous computing, tangible interfaces and physical computing manifest through the interconnectivity of many technological protocols, such as radio frequency identification tags, high-bandwidth, long distance wireless networking, and act on different scales of architecture, from smart buildings, to facial recognition systems and networked health monitors that instantly inform about our physiological performance. Greenfield's concept of everyware overlaps with the notion of the Internet of Things, added to relevant social reflections about the political implications of ubiquitous/pervasive computing technology (figure 2). His discussion brings important contributions to the debate about ubiquitous computing, specially regarding the discussion of how the colonization of everyday life by information technology is weaved in different scales of network architecture, from the biological body to the ideological institution; and also about how ubicomp is strongly implied as a political agenda of security post 9-11, as a tool for surveillance and control.

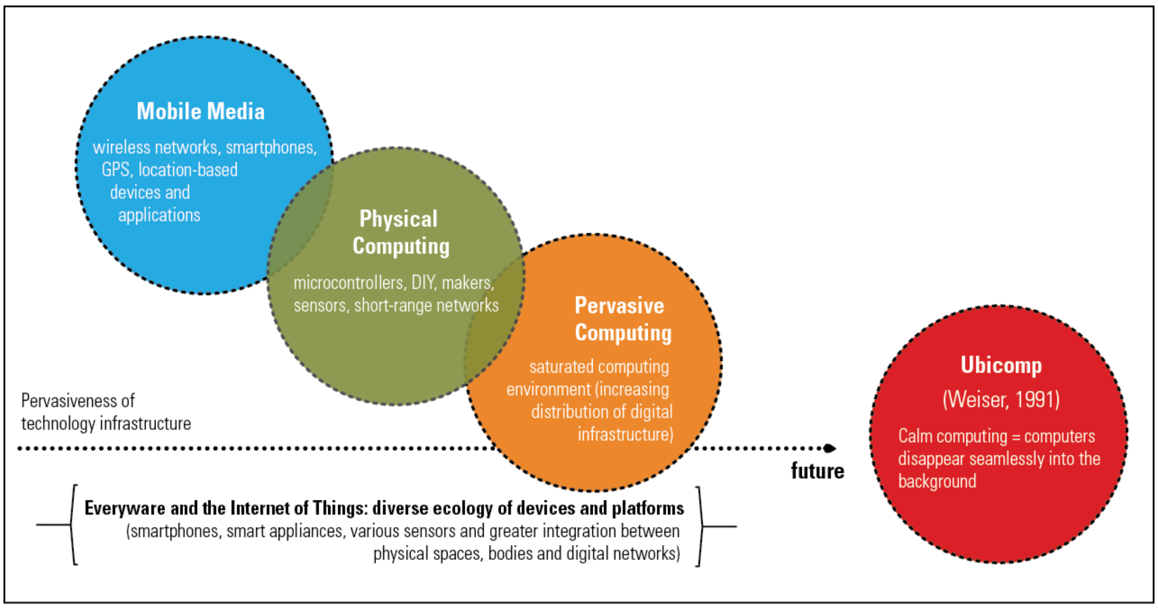

Figure 2: Conceptual and social imaginary of the Internet of Things.

The current state of networked computing is not quite the calm computing scenario that Weiser and the team at Xerox PARC described (Weiser and Brown, 1995). Dourish and Bell (2011) argue that it is still quite messy. It is characterized by a profusion of devices, competing operational systems and protocols sharing an over loaded wireless internet bandwidth. It is noisy and disruptive, as the inconstancy of network connectivity often reminds us that wireless infrastructure is unequally distributed, and even when connected, that net neutrality is a concept that is not in operation. We are somehow in between the post desktop paradigm and a more advanced stage of embedded pervasiveness; in a stage where computing devices are not merely portable, but also mobile. However, they are still not entirely dissolved into the background.

Dourish and Bell (2011) provide us with a productive critique that explain why Weiser's vision (1991) might never happen. Research in ubiquitous computing operates under a speculative framework that is constantly focused on the next degree of technology development, instead of the current one. The near future tense that persists in ubicomp research prohibits researchers to realize that ubicomp is already here and working—however in different ways that Weiser predicted. Ubicomp researchers, according to Dourish and Bell, are stuck trying to build the 1980s vision of the future. The use of near future tense contributes for not holding researchers accountable for their findings, which then become an exercise of imagining scenarios. The completely seamless and pervasive world of computing that was imagined by Weiser might never arrive because of the inequality of infrastructures, regulations, literacies and cultures. In contrast with the gleaming seamless interfaces of the mythological digital future of ubicomp, Dourish and Bell acknowledge that the "mess" of the actual technological landscape is a property of the technological infrastructure. The "mess" is an integrative part of the heterogeneous assembling technologies that composes the ubicomp model at work.

Unequal technological infrastructure, the digital divide, and literacy also evince that human computer interactions bend more strongly towards opaqueness and are mainly marked by disruption and moorings than free flow. All this could make us think that such naturalization of HCI as depicted by Weiser (1991) is unthinkable, not only because the often awkwardness in our interactions with technology reminds us that they are tools, but also because the models of human computer interaction will never be homogeneously seamless, equally available or distributed in the world. But still, as much as his prediction might not take these aspects into account, we must interpret Weiser's imagination of human computer interaction and ubicomp through the paradigm he proposes. Weiser sees ubicomp as a network of multiple and heterogeneous elements, computing machines embedded in human environments where human computer interactions are *pervasive embodied virtualities*. It is the constitutive aspect of this *embodiment* that I want to call attention to. Weiser counterposes ubicomp to Virtual Reality (VR), therefore this virtual embodiment he talks about has to be different from what VR proposes. While VR (back in the 1990s, at least) makes a virtual world the focus of attention, accessible through a screen or goggles, and "focuses on an enormous apparatus on simulating the world rather than on invisibly enhancing the world that already exists" (Weiser, 1991, p. 94), ubicomp refrains from focusing attention in one spot and values the multiplicity of points of surfaces of access. While VR folds *out* to a separate alternative reality, ubiquitous computing folds *in* virtual embodiments of human and things. The naturalization of HCI that Weiser predicts, with "information available at our fingertips during a walk in the woods" (1991, p. 104), could be understood as not entirely focused on the seamlessly and transparency of the interface but also on the familiarity we acquire with computational embodiments, available not through computational-windows but as computing things in themselves.

While we are not in an entirely ubiquitous computing reality, computing capacities have already achieved a deeper level of pervasiveness in our physical environment. Departing from Weiser and Brown's (1995) vision of calm technology as criteria to define ubiquitous computing, pervasive computing is a stage towards that ideal. I understand the Internet of Things as a contemporary social network application that includes context-aware hardware and location-aware environmental infrastructures.[28] Furthermore, it is a strategy to engage with the internet that is materialized through new spatial and corporeal practices.

In order for a ubiquitous computing network to be pulverized and efficiently disseminated everywhere, access points must also be distributed. In other words, not only big, already established corporations have to buy in the concept of a pervasive and ubiquitous internet, but so does a network of institutions and communities of users and independent inventors. As Weiser's predicament was turned into a research agenda for Xerox PARC and other tech companies, its imaginary was also present in hackerspaces and later in makerspaces,[29] as hackers and tinkerers expanded their focus of attention from software to hardware hacking. By tweaking already available hardware and creating hardware prototypes from scratch, hackerspaces became a fruitful environment for grassroots open technology development in sync with the pervasive computing trends. In the following section, I provide a brief overview of the rise of the maker movement

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[28] Federal Office for Information Security. pervasive computing: Trends and Impacts. Available at https://www.bsi.bund.de/SharedDocs/Downloads/DE/BSI/Publikationen/Studien/Percenta/Percenta_eacc_pdf.pdf?__blob=publicationFile

[29] The practice of hacking, what constitutes a hacker's ethic and what is a hackerspace are objects of controversial debates. For the purpose of clarification, I follow the definition of hackerspace defined by Kostakis et. al (2014), which defines it as "the physical, community-led places where individuals, immersed in a hacker ethic, are to be met with on a regular basis engaging with meaningful, creative projects" (p3).

through the establishment of hackerspaces as they were setup independently and often in institutions such as universities, foundations, and non-profit organizations.. Following, I discuss how critical making as a research method relates to the tinkering practices native to the maker movement.

The maker movement and critical making

The maker movement is composed by DIYers, technology hobbyists, entrepreneurs, tinkerers and enthusiasts of "open hardware" initiatives who explore hands-on problem-solving and prototyping in small scale as an alternative mode of production of technology and physical goods. The maker movement grew inspired by the "hacker culture" and was impelled by a combination of factors: First, the success of our mass scale industrial model of production created a surplus of hardware, which made hardware parts more widely available and affordable (Mota, 2011). Second, the development of small scale manufacturing technologies, such as 3D printing and micro-controllers. And third, the increasing interest in technology literacy materialized through various lines of government funding for the creation of hackerspaces, makerspaces, and private initiatives such as: publications (i.e, Make Magazine, O'Really Media Make book series), events (i.e., Maker Faires), and commercial chains of digital fabrication workshops (i.e., *fablab*[30] TechShop).

The "hacker culture" is a political expression of technology appropriation and a practice that has been under deployment since the 1960s in Europe and in the U.S. Throughout decades and generations, it encompasses a wide variety of computer related

[30] Fablabs, or fabrication labs are workshops composed by small-scale tools for digital fabrication. The use of the terms fablabds, hacklabs, kackerspaces, makerspaces is often interchangeable. Please refer to Maxigas (2012) for further conceptual differences between hacklabs, fablabs and hackerspaces.

practices, some considered illegal and criminal, and mostly motivated by the premises of freedom and access in the realm of information technologies. Although practices vary among groups of hackers, there are common principles that constitute a hacker ethic (Levy, 2001). These are free access to technology and information; decentralization of authority from governments and private companies to a system of meritocracy, and focus on self-improvement—for the hacker community and the individual. Based on these ideals, hackers formed online and offline communities to share knowledge, tools and collaborate in projects. By the early 1990s, this first wave of hackers had organized themselves in a more systematic way and started to share physical spaces named hacklabs (Anon, 2008). The first hacklabs[31] appeared in Germany[32] (Farr, 2009, Kostakis, Niaros, Giotitsas, 2014) and they were communal laboratories mostly composed by reclaimed/recycled GNU/Linux machines that provided physical and virtual infrastructure to hackers. They were focused on running workshops on programming, electronics, and independent radio broadcasting, (Yuill, 2008) with a strong ideological agenda based on the democratization of communication infrastructures. These early hacklabs derived from a long lineage of activism, and are tied to a broader political movement of anti-capitalist resistance and democratization of European regimes. They worked as a bottom-up organization to foster technology experimentation where participants could share knowledge, build collaborations and get technical support.

Current hacker and makerspaces emerged from mid-2000s onward and share this same model of collective production of technology but also differ from the first wave of hacklabs in significant ways (Maxigas, 2012). While the first hacklabs (i.e., C-base in

[31] Id.
[32] C-base in Berlin and C4 in Cologne.

Berlin and C-4 in Cologne) were mostly focused on open software, current hacker and makerspaces are more focused on hardware design, sensors and networking devices into the Internet of Things. While initial hackers were more invested in programming and coding, current makers are more invested in exploring the possibilities of micro-controllers, 3D printing, laser cutting, and as researchers of ubiquitous and pervasive computing, also bridging the physical and informational layers of the internet. Current hackerspaces also differ from previous ones in their relationship with established institutions. While hacklabs were clearly anti-institutional and marginal—and in some extremes, even operated underground—hacker and makerspaces are being built inside schools and private companies as strong components of a broad educational effort to foster innovation in technology production.

The Obama administration, for example, created the "Maker Education Initiative" (MEI)[33] in May 2012 to incentivize public and private partnerships in STEM (science, technology, engineering and math) education. The consortium that sponsors this initiative is lead by Make Magazine's Dale Dougherty, and composed by Maker Media, Cognizant, Intel and Pixar Animation Studios. MEI's main focus is on the expansion of hacker/makerspaces in schools and after school programs, and the development of mentorship programs for all ages. Following this initiative, DARPA (Defense Advanced Research Projects Agency under the U.S. Department of Defense) launched a US$12.5 million MENTOR[34] (Manufacturing Experimentation and Outreach) program in partnership with Otherlab and Make Media to build 1,000 makerspaces until 2016. DARPA is best known for funding strategic research projects such as networked

[33] http://makered.org/
[34] http://makezine.com/2012/01/19/darpa-mentor-award-to-bring-making-to-education/

computing, mass surveillance, biotechnologies, and others that are capable to guaranteeing the U.S. a leadership position in world defense and military forces. In June 18th 2014, President Obama declared the National Maker day, hosted the first White House Maker Faire.[35]

China is implementing similar initiatives despite the restrictive Chinese policies for information technologies and censorship of internet access. According to Silvia Lindtner (2014), calls for proposals sponsored by the Chinese government are enabling the creation of “innovation houses” as part of a larger platform to foster innovation and creativity. Known manufacturing centers such as Shanghai and Shenzhen have been opening hacker/makerspaces since 2010; an initiative that Lindtner (2014) discovered that is tied into shifting the Chinese economy from purely manufacturing and assembling (“made in China”) towards design and innovation (“created in China”).

These policies evince how the economic shifts brought by the network society (Castells, 2010) demand that new modes of production and labor are developed. Wikipedia and Kickstarter are examples of successful business models based on collective production and sharing developed to accommodate the new phase of industrial capitalism. The implementation of these policies are also evidence of how the egalitarian expectations deposited on the political effects of democratization of information and the availability of open software and hardware do not imply on transcendence of a capitalist mode of production.

The maker movement lives in great ambivalence. Makerspaces derive from hacklabs and the hacker subculture as their governance relies on key aspects of hacker

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[35] https://www.whitehouse.gov/the-press-office/2014/06/18/fact-sheet-president-obama-host-first-ever-white-house-maker-faire

ethic such as a meritocratic system and individual empowerment. At the same time, makerspaces became widely available when their installation was inserted into governmental and corporation strategies to incubate new technologies to be later made available at the marketplace.

Nonetheless, makerspaces installed in universities and research institutions are being used through multidisciplinary approaches in ways that explore the diverse applications and implications of technology appropriation and critique. Matt Ratto, at the University of Toronto, is a leading scholar in this field and since the early 2000s has been developing a "critical making" method to organize the projects under development at the Critical Making Lab.[36]

Matt Ratto, in an interview by Garnet Hertz (2012) tells us how critical making encompasses different making practices (design, art, tactical media), how it articulates social studies of technology engaged with deep reflection and holds the potential for social intervention. As a research method he has been developing since the 2000s, Ratto develops a genealogy of critical making from Critical Theory while addressing the gaps that Critical Theory (specifically the Frankfurt School) left regarding material production as a means of critical reflection. Through the exploration of different ways to engage with materials and technologies, critical making puts in practice the idea of material semiotics

[36] By 2015, makerspaces and media labs installed in technology focused graduate programs are common infrastructure and research methods in design and social sciences are being developed in articulation with these spaces. To see other methodological approaches regarding making and makerspaces see Natalie Jeremijenko and Eugene Thacker's "Creative Biotechnology: a user's manual" (2004) at http://goo.gl/jSOO6Q and Agre, P. E. (1997). Toward a critical technical practice: Lessons learned in trying to reform AI. In G. Bowker, L. Gasser, L. Star & B. Turner (Eds.), *Bridging the great divide: Social science, technical systems, and cooperative work* ()Erlbaum.

where objects are not only linguistics artifacts but also the materialization of our meaning making process.

Through critical making, Ratto (2012) questions the pretense divorce between the activities of thinking and making. Critical thinking is commonly thought as an intellectual linguistic activity that takes form in verbal discourse. Meanwhile making is commonly understood as unreflexive, aprogrammatic, self-contained mechanic actions. Critical making comprehends the overall process of material engagement with technologies, that is reflexive and informative about how the world is while at the same it deconstructs and opens up new articulations for how we relate to technology and society. Ratto (2012) states that critical making is not focused on making functional technologies, in the way that the making process is geared towards a final object—"Critical making emphasizes the shared acts of making rather than the evocative objective" (p. 253). Instead, it is focused on the broader lived experience of making and understanding the broader social implications of technological practice. It is in this aspect that critical making as a method of investigation distances itself from prototyping. Both might use the same infrastructure of maker/hackerspaces, but the forms of engagement with the technology differ. While critical making embraces the process as an exploratory enterprise and allows the material affordances to guide the making process, prototyping follows strict predefined guidelines that are goal oriented and material choices tend to be a secondary consideration. Experimentation in prototyping is exercised in conformity to a modern episteme of the scientific method, where the researcher tests predefined hypothesis in a controlled environment to obtain "accurate" results that will progress the experiment towards the research goal. Experimentation in critical making is one that is focused on the emergence of the experiment *per se*; it is based on bottom-up creativity and negotiated through the affordance of materials, the investment on reflecting upon our process and the uncertainty of outcomes.

This vision of experimentation adopted by critical making draws on three aspects of constructionist pedagogy (Ratto, 2012). The first aspect is the emotional dimension of learning, which encompasses the mental energy, feelings and motivations that are influenced by the cognition or understanding. The affective ways in which the researcher engages with the meaning-making process adheres to the researcher's personal investment in the experimentation. The second aspect is the use of transitional objects—in the case of this dissertation's experiment, the micro-controllers, the sensors, and the computer. These objects materialize abstract cognitive processing and bridge the motor and cognitive knowledge. According to Ratto (2012), "these objects do not just serve to illustrate' concepts, but act as means for projecting oneself into an abstraction" (p. 254). And lastly, the third aspect refers to the importance of "messing about" computers (Ratto, 2012) as a strategy to foster unstructured and autonomous exploration on how technology works.

By drawing from Ratto's approach of critical making, I developed the interactive installation "Truth or Dare: a mobile moral compass for ethical living" (ToD) as a way of engaging with the materials and technologies that relate to the research questions I investigate. From this engagement, I was able to supplement and extend critical reflection and reconnect previous theoretical discussions regarding digital media, body, and power with the lived experience of making. Thus, I do not consider ToD as a methodological tool to collect data in the positivist approach of science as an instrument of verification of truth. I consider the experiment of making, interacting with and observing the interactions of others with "Truth or Dare" as a mode of composition that engages in dialogue with the theoretical and analytical components of the research.

In the next chapter I present an account of the making process of ToD and the setup of the installation in two exhibits. The first exhibit was in April 2013 at the Hunt Library for the CRDM Research Symposium[37] and later in May 2014 at the Interface Interference Smartphone Art Show[38] at the Carrack Modern Art Gallery. This account describes the building process and demonstrates how tinkering fosters reflection beyond technical problem solving and provokes critical thinking.

In the next chapter I hint on how the process of making ToD and the interactions that took place in the exhibits animate the discussions that are central in this dissertation, and that are further developed on chapters 3 and 4. ToD informs how the biological (analog) and computational (digital) materials interface, how the build and use of sensors somehow organize forms of knowledge regarding physiological standards, and how this standardization informs social norms of validity. Validity is defined not only in terms of truthfulness of statements, but expanded as a measure for validity of practices; in fitness tracking devices, for example, in which sensors are used to measure parameters for good health. Ultimately, the observations of the Quantified Self forum and the interactions with ToD inform how pervasive computing technologies organize practices of self-making, how they territorialize the biological body through the mapping of physiology

[37] http://crdm.chass.ncsu.edu/sites/symposium/2013

performance and how the generation of big data weighs in the governance of the user's privacy, sense of intimacy, and the negotiation of safety and risk.

CHAPTER TWO

"Truth or Dare": A critical making experiment

Truth or Dare was conceptualized while I investigated Michel Foucault's thesis on the interrelations between power, forms of knowledge and subjectification (Foucault, 1965, 1970, 1972, 1973, 1978, 1984, 1984a, 1985, 1985a); and explored the possibilities of knowledge production using sensors and micro-controllers in physical computing projects. Foucault's constructivist approach to reality through typification of cultural codes along with critical reflections of computer coding as a mode of composition motivated the inquiry on the use of physical computing technologies—specifically sensors—as representational probes to access and assess reality. The design for the Truth or Dare (ToD) interactive installation departed from the Foucauldian concept of "games of truth" and "technologies of the self" (TEF, 2003) and teases how the knowledge of what is "true" and what is the self are productive creations through technology. I explain this further.

Foucault's life work lies in the interrelationships between power forces in relation to immanent forms of knowledge and modes of subjectification. He argues that all knowledge is irremediably tied to the exercise of power relations. Therefore, there cannot be an "objective knowledge," and all claims of this objectivity are nothing more than acts invested of another sort of power. "Objective knowledge" gives place to different dynamics that revolves in the intermeshes of power, knowledge, and subjectification. Because the subject is placed in relations of production, signification and power, Foucault advocates that the construction of knowledge—or "truth"—should *not* be analyzed from the point of view of an internal rationality—science, church, etc.—but through the antagonism of discourses, actions and technologies (TEF, 2003).

The relations that are established between the subject, forms of knowledge and plays of power constitute experiences as an affect of normalization in the order of the sensible, in the construction of *savoir* (the particular conditions that underlie an object of knowledge or the formulation of an enunciation) and in the architecture of *connaissance* (the corpus of knowledge, i.e., biology). A major implication of this shift is the denial of any aprioristic categories of the self, objective knowledge, and therefore, truth. And with that the impossibility of either to be constituted as autonomous entities revealed through universal experiences of discovery. The construction of knowledge, truth, and the strategies of verification and validation of truth emerge within historical experiences and act on—as are produced by—subjectification (TEF, 2003). The specific technologies that shape systems of representation that we use to understand ourselves, called by Foucault as "games of truth" (TEF, 2003) are the strategies that fabricate what is historically defined as truth, normal, and hegemonic. To account for what is truth, as a historical productive force and the product of history itself, we must construct a historical ontology of the self. Foucault's concern does not echo with establishing how the discovery of truth (theory) gets closer to truth itself (reality), but understanding that whatever truth is, it is rooted in the discourses that knowledge maintains with itself and with the subjects. The theories that emerge within these discourses are part of the history of the discourses; not as an abstraction, but as affects and practices.

The biometric premises that animate ToD and the strategies that shape the interactions in the installation evince the contemporary technological dynamics of power-knowledge-subjectification that “create a history of the different modes by which, in our culture, human beings are made subjects” (TEF, 2003, p126). ToD is a technological arrangement that produces historical modes of subjectification in relation to truth—as we are subjects of knowledge; in relation to a field of power—as we are subjects and apparatuses acting on one another; and in relation to morality—as we are biopolitical agents.

ToD explores modes of subjectification as practices of self-making and of governance of the self (as the user monitors her corporeal performance), and (games of) truth as normative practices of governing knowledge (as physiological data is conferred true or false values). The application of galvanic skin response sensors as biofeedback measures demonstrates how biometrics becomes a technological protocol and how it is used as a mapping tool for the body’s performance. The physiological data, technologically rendered, is translated in terms of moral standards (truth or lie) and social norms (criminalization of lie). The forces of social-biotechnological assemblages emerge in the iterations, controversies and conflicts when there is a mismatch between emotional response and discursive performance of the tweets. Furthermore, ToD ambushes the use of sensors and micro-controllers as objective probes of the physical world. The parameter of programming languages that processes the collected data has gone through a “threshold of formalization” (Foucault, 1970). While ToD defeats the applied logic of if/then statements of programming language as a feasible correlation with the complex dynamics of life, it also calls attention to how this pretense logic of neutrality conveys a layer of normalized ideology. If we view command lines as statements (as in Foucault’s definition in the *Archaeology of Knowledge,* 1972), we can understand them not only in terms of semantics (i.e., if the collected data value is over the stored data threshold, then add #lie) but also in terms of the large discursive formation in which they occur (i.e., the expectation and desire of calculable standards for moral behavior, the social premises and moral standards defined by biofeedback measures). Command lines/statements take shape not only as functional tools for software programming but also as a machinic discourse which problematizes the historically situated power network it is interweaved in.

In this chapter I present a narrative of the critical making process of "Truth or Dare: a moral mobile compass for ethical living." The first section of this chapter describes the build of ToD and covers the hardware tinkering and the code writing. The second section describes the installation setup and the exhibits ToD took part of. During both sections I hint on the critical reflections triggered by the making process. These observations are further explored in the upcoming chapters in the analysis of practices of self-making and power through pervasive computing technologies. I conclude with a summary of the observations that marked the interaction of ToD with the users in the exhibits.

Building Truth or Dare

I decided to approach the built of Truth or Dare with the meticulous mindset required by prototyping and the ironic attitude[39] typical of tactical media practitioners. While ToD is a provocation and my scholarly background set me up to challenge the premises of a lie detector, I still meant to go through the building process as if it were a

[39] Irony, satire and parody are recurring rhetorical devices adopted by media activists and artists to call attention to the politics of media. From the International Situationists, to Dada and the Yes Men, the appropriation of different takes on humor operate as a tactic to enact power and expose the ridiculous. For more on the use of rhetorical devices on Tactical Media see Raley (2009).

functional device, based on the premises of biometrics and correlations argued by behavioral science. For that I read patents and journal articles that detailed the inner workings of the lie detector machine and how to calculate the thresholds that define the boundaries between true and lie.

The first step towards the design of the installation was to search previous builds of physical computing projects that dealt with biofeedback as analog reading input. Micro-controllers enable two types of input: analog and digital. Analog inputs are electric values that vary continuously within a range, such as voltage and resistance. Examples of analog sensors are brightness sensors, temperature, heart rate and humidity. Digital input, on the other hand, is based on a binary logic and functions as an on/off switch. The digital sensor detects presence or absence of voltage and in turn generates a logical 0 or 1 to characterize the off or on state of the circuit. In a household, a light switch with a dimming option works with an analog input, which controls the gradation of electric current that goes to the bulb, while a simple on/off switch is a digital input. Because micro-controllers operate on a digital basis, all electric input (analog or digital) is converted into digital signal. In the digital input, the conversion of presence or absence of voltage takes shape in the binary 0 (off) or 1 (on). In the analog input, the voltage variation is translated into values that range from 0 to 1023.

Based on previous builds available on Make Magazine,[40] makers' websites,[41] and my previous experimentations with the analog sensors aforementioned, I put together

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[40] See the build for the Truth meter available on Volume 26 of Make Magazine available at http://makezine.com/projects/the-truth-meter-2/.

[41] See the Biosensing project by Tom Keene available at http://theanthillsocial.co.uk/projects/biosensing and the Truth Wristband kit by Sean Montgomery available at http://www.produceconsumerobot.com/truth/

different versions of the micro-controller+sensor combo, starting with an Arduino[42] and wired sensor similar to the Truth Meter project, a DIY lie detector prototype developed by Make Magazine (figure 3). I provide the account of the actual build as I describe the analog sensors setup (step one), the challenges in processing analog data (step two) and in establishing communication protocols among hardware and software platforms (step three), and the creation of the mobile app (step 4).

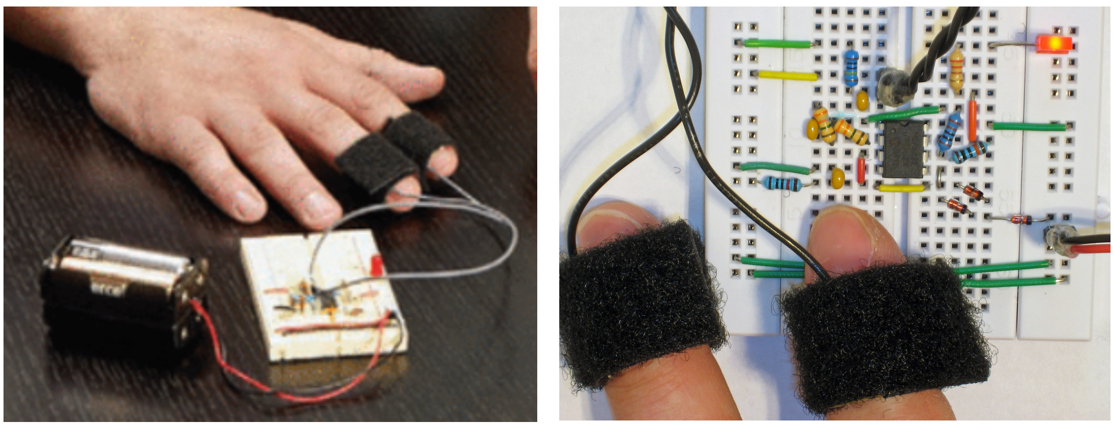

Figure 3: The first version of ToD followed the Truth meter hardware design. Images above are of the Truth meter setup.

Step one: I built the first version of the galvanic skin response sensors by soldering two pieces of insulated wire to two pieces of copper foil. I then attached the each piece of copper foil to velcro tape and wrapped them around my fingers as cuffs. The other ends of the wires were connected to the Arduino board, which in turn was connected to my computer via USB. One of the sensor wires was connected to the +5v pin—sending that voltage through my body—and the second wire was connected to

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[42] The arduino is an open source physical computing platform based on a simple input/output (I/O) board. For more information about the platform see http://www.arduino.cc

ground and an analog pin—turning my body into a resistor made of flesh, while the analog pin collected the variable amount of voltage that made through my body. Based on the Arduino library reference, the Truth Meter circuit and bits of code shared on specialized forums, I put together a program that used the analogRead() function to map the voltage amount (analog data), and print the state values on the serial monitor in the Arduino development environment installed in my computer. I also bridged the sensor data to a processing program to print a live graph—that continuously draws itself while the program is running and data is being collected—to more easily visualize the variation of the data input. The digital converter internal to the Arduino board translates the analog voltage values into comparable integer values (digital data) ranging from 0 and 1023. The Arduino's digital converter yields a resolution of 4.9mV (5V divided by 1024 units) and can potentially provide a reading rate of 10,000 values per second. That means that with no delays in processing, I could get 10,000 numeric measures of how much voltage goes through my body in each second. I could observe the numerical sequences that codify the varying amount of electric conductivity in my body and—potentially—witness the moment in which my emotional state is codified into a false statement. While the program printed the numeric values of the data as it was being collected, it also drew a graph on the computer

Feedback is crucial in this setup. The ability to efficiently collect the data is useless if the output is not made legible to the user, thus allowing the interaction with the system to go full circle. For that reason, I included a LED to the board and added an if/then statement to the program. This program stipulated that if the value read by the analogRead function was greater than X, a digital output would turn on the LED to indicate to the user that a lie had occurred. This behavior emulated the final setup for the installation as digital output was the trigger to turn on the beacon lights and to add the hashtag #lie or #true to certain tweets. As I got my first readings I quickly got proof of the speed of the Arduino's digital converter. Values populated the terminal window and I could not keep track of any of them. After running the program for a while and examining the data log, I also noticed the randomic aspect of the numbers. My expectations were to be able to establish a somewhat stable temporal curve and to be able to identify variation in situations that I simulated stress, but the readings I was getting showed a huge variation that did not characterize any patterns.

<u>Step two:</u> in an attempt to slow things down and equate the Arduino processing capacity to my own eye/brain, I entered a delay and a smoothing function to the program. The delay paused the program after each reading, which was critical for the practical purposes of the installation so the user could easily assess the output of her participation. The smoothing function collects the measured values in an array and calculates an average of these values. Each new value that is collected is summed to the others in the array and divided by the number of units, generating continuously smoother data. It is a popular strategy among programmers to "smooth" erratic values and control the level of noise in the system. While these measures provided me with a more controlled environment, I was still facing difficulties producing reliable correlations between the emotional state of the human and the output measured by the system. When I took voltage measures in different points of the circuit board, I realized how inconsistent these measures were with the theoretical setup. I replaced resistors—in case they were faulty—but the inconsistent measures pointed to another possibility. When the source of power is

inconsistent—in this case probably due to the Arduino limitations to send out 5v of power in a continuous manner—some components of the circuit hold on to residual voltage, which interferes with the entire electric flow in the circuit. To approach this issue, I tested different combinations of resistors and capacitors. The role of the capacitors is to filter the current longer frequencies and diminish the erratic behavior on the other electronic components.

To build a functional interactive system, it is necessary that the automated operations are consistent and that the environmental conditions are under control. If you run a program in a simulated environment where noise and variables are under control, i.e., using a simple calculator, two plus two will always result in four. However, when variables are processed through transcoding analog data, subjected to the interference of external factors such as magnetism and voltage noise, the output of that data can be quite unpredictable. Working with physical computing components demonstrates how soft hardware can actually be. The transition from electrical calculators, tabulators and analog computers (i.e., Turing's machine) to digital computers has turned these machines into media processors that are not physically manipulated on the hardware but through software interfaces (Manovich, 2011). In consequence, a myth of separation of the (hard) physical and (soft) computing layers has endured the notion that hardware is stable, while the programmable software is the entry to transcode the world into digital data. However, my experience with these physical computing components demonstrated how the assumption of hardware stability is deceiving.

After these adjustments, I tested the ToD on myself and observed the data collected by myself, absent from any other form of evaluation or judgment than my own.

Given my skepticism towards the premise of a lie detector—that it is possible to identify truth or falsity through biometric readings—I found to be aimless to test it on myself by evoking statements that I knew to be true or false, as my emotional response would not correspond to my verbal expression. Colleagues that volunteered to test ToD shared that same skepticism and faced the experiment as a gimmicky game; as any lies that were said did not have any consequences or impact and thus did not evoke an analogous emotional response. For that reason I focused on testing ToD by evoking emotional responses—by evoking stressful memories (personal, lived situations that affected me emotionally) and looking at sensitive imagery—rather than expressing verbal statements, as the first are more immediate and spontaneous.[43]

Step 3: The construction of truth is a social and cultural event and while the hardware and the program functioned consistently based on the premises of a typical lie detector, when used by itself it could not mimic the social complexities of moral judgment. For that reason, I decided to interface the program with Twitter and instead of assessing oral communication, I decided to assess written tweets. I had previously worked in two projects[44] (Selves Reflexives No. 1, 2012, The Sentient Room, 2013) interfacing Twitter and Arduino platforms.

One was a recreation of bpNichol's programmed poem "Self Reflexive No. 1." (1984). Originally designed in Apple II language, the poem consisted of an animation of the sentences "Dream you Lost," "Toss all Night" blinking and moving down the screen. The recreation of the poem consisted of reprogramming it in Processing. In the

[43] However I don't mean to imply that emotional response is more genuine or authentic than verbal expression. Emotional and verbal responses are both socially conformed.
[44] These projects were developed with Samara Mouvery and Brent Simoneaux, also CRDM students.

foreground of the screen, the sentences were drawn perpendicularly, crossing each other. In an interval of a few seconds they would toss around each other and replicate themselves. In the background of the screen, a “wallpaper” of tweets was brought together. The program, in interface with Twitter, searched for tweets about insomnia and drew them, line by line, in real time. In this way, the code broke down with the self-containment of the original version of the poem and reached out to public manifestations of self-disclosure about lack of sleep.[45] The level of personal disclosure in bpNichol’s poem and the common use of social media to publicize private information prompted thinking about physical spaces that could be analogous to the sense of great privacy and secrecy.

The second project was an installation named “The Sentient Room”[46] (Duarte, Mouvery & Simoneaux 2013). This installation recreates a psychiatrist’s office. The room is composed by two main pieces of furniture, an armchair and a chaise, situated amongst other mundane objects—rugs, end tables, lamps. Individuals interact with this environment as they do with any other pieces of furniture in their daily lives: They sit on the chair, shift their weight while sitting, wiggle, get up from the chair to leave. This mundane interaction with the furniture, however, prompts the unusual. Every time movement is sensed, the furniture sends a tweet, drawn from four theorists in their original languages.[47] An open window is projected onto one of the room walls (figure 4).

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[45] A video of a live recording of the animation is available at https://www.youtube.com/watch?v=4ewPryEINYA. Retrieved in April 2015.
[46] Video available at https://www.youtube.com/watch?v=RtUhR8p-zrc. Retrieved in April 2015.
[47] Tweets were sent from a database of text excerpts from Giselle Beiguelman, Gilles Deleuse, Vilém Flusser and Martin Heidegger.

Figure 4: The setup of the Sentient Room.

Looking through the window, texts are visualized as information flowing through an urban environment. The installation visitors and the tweets are simultaneously in the room, and also distributed, potentially accessible from any location around the globe. By following the individual accounts of the furniture or by following the hashtag on Twitter, users can trace the intertwining of texts as they emerge from the space in real time.

To establish an interface between Twitter, an online platform, and the Arduino programs for the two projects—“Selves-Reflexives n1” and “The Sentient Room”—I used a java library—*twitter4j*. While this solution worked for these projects, when the Twitter API (application program interface) was updated by the company, the interface with the Arduino program became intermittent and often unresponsive. This situation forced me to look into other library alternatives and micro-controllers to setup the “Truth or Dare” installation.

Twitter is an application characterized by fast, short and mobile communication. Thus I decided that I also wanted to make the ToD program available as a mobile application, running in a smartphone in interface with Twitter's mobile app. For that I also needed to ensure that the hardware was portable and had wireless connectivity. Therefore, portability and feasibility of mobile interfaces were the main criteria when I looked into other micro-controllers. The solution that I found was the IOIO board (figure 5).

This board was designed to interface general input/output peripherals with Android devices. A lithium battery powers it and a Bluetooth dongle transmits data wirelessly between the board and the smartphone. I adapted the galvanic skin sensors on the tin can, and for the conductive material, I used pennies instead of copper foil (figure 5). Similarly to the Arduino, the IOIO board also has a development environment for programming. Differently form the Arduino, the language for the IOIO is java.

The following step was to rewrite the program in java that had been originally developed for the Arduino. At that moment I consulted with java developers[48] to establish the communication between the board and the ToD app, and between the ToD app and the Twitter account.

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[48] Leonel Galán, a developer at Stealz, was a fundamental asset for this development.

Figure 5: The IOIO board was mounted on a metal thin to enclose the battery and the Bluetooth dongle. The pennies functioned as galvanic skin sensors and were wired to the analog pin on the board. The circuit setup was similar to the one setup in the Arduino. Resistors and capacitor values were maintained. The LED indicates when the board is on use.

Step 4: during the recreation of the program, I made a further development on the mechanics of truth/lie assessment. When the IOIO board is powered and held by the user—in a way that her skin is in contact with the sensors— she starts the ToD app on her smartphone and the board collects and processes data and relays it back to the ToD app. I called this start up stage as "calibration." During the calibration stage, the app calculates averages of these initial values and stores them in an array. When the user is ready to write the tweet, she presses the button “Type Tweet.” By pressing that button, she ends the collection of “calibration” data and starts a collection of a new array of data. This latter array holds the value that in the end will be compared to the initial value, and this comparison defines whether the statement was true or false. The introduction of a calibration stage allowed for the creation of individual baseline values instead of a universally fixed threshold for “truthfulness.”

The ToD app interface went under small alterations in relocation of buttons and text fields between the two exhibits. The final version of the app interface is showed in figure 6. I numbered the components of the interface in order to explain each component’s function:

1. This is a text field where the user enters the login handle for the Twitter account. I made
2. a smartphone and a tablet available with the app installed in both exhibits that ToD participated. In both devices, the app had been synced with the “apptruthordare” Twitter account. Participants in the interactive installation were tweeting from that account. This allowed participants who did not carry an android smartphone, would not rather install an app to their phones or do not have a Twitter account to participate in the installation. It also ensured that I had access to the entire data set of tweets that were sent out.
3. While touching the sensors and the device, the participant must press the button “Type tweet.” The function of this button is to add a time stamp marker to the string of data being collected by the sensor. When the button is pressed, the app marks that moment

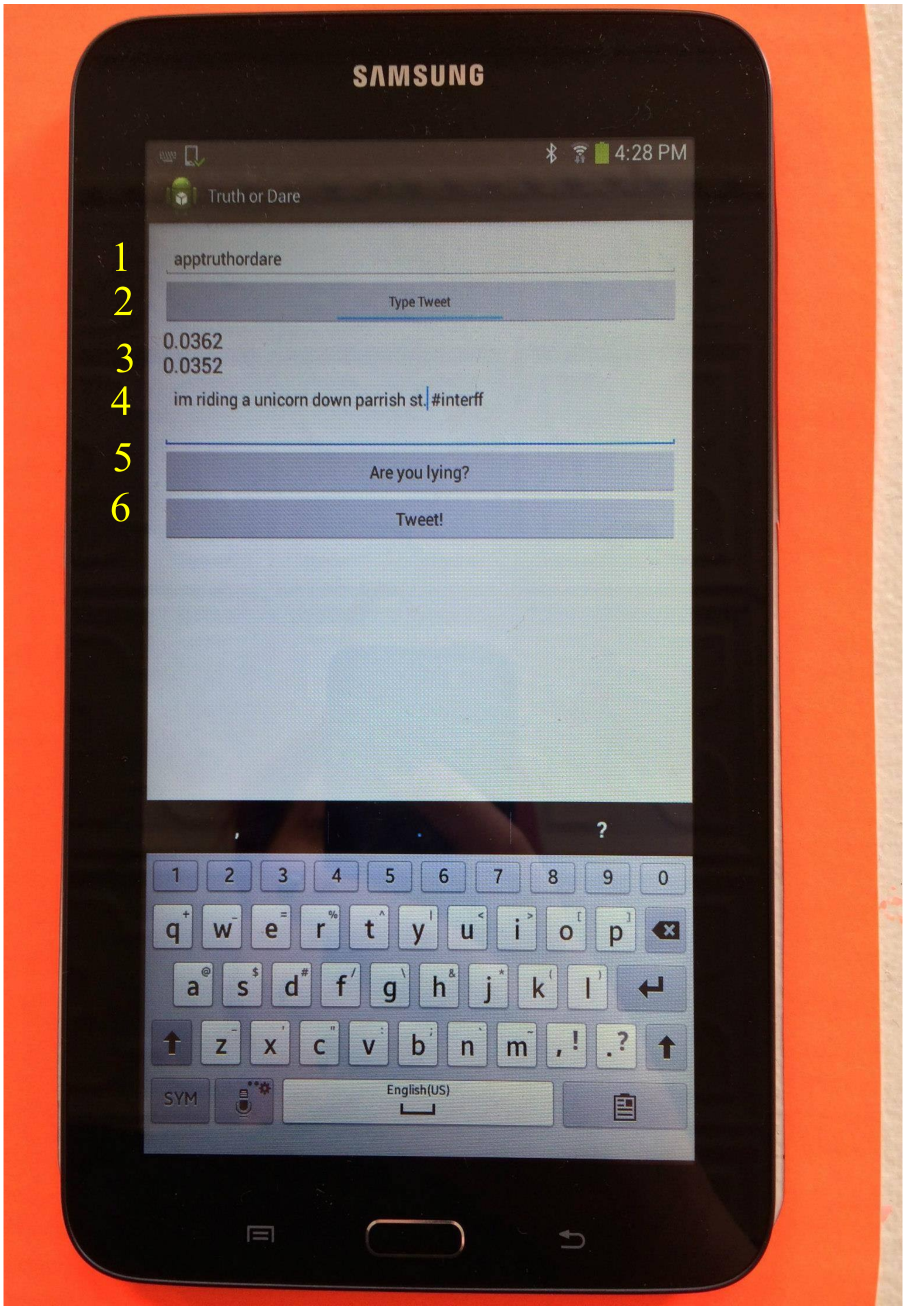

Figure 6: Truth or Dare app interface.

as the end of the calibration phase and saves that value as the baseline value. This value is obtained through a calculation of the average of the values (one hundred values collected per millisecond) collected during the time the participant held the sensors up to the moment she pressed the button.

4. The top number is the average calculated within the time span from the moment the user first touched the sensor up to the moment she hit "Type tweet." The bottom number is the current value (a second average calculation) collected while the user types her tweet.
5. In this text field, the user types her tweet in the form of a statement.
6. After the tweet is typed, the user presses the "Are you lying?" button. The function is trifold. First it adds another time stamp marker to the string of data being collected by the sensor. It saves this averaged value to be compared to the baseline-averaged value. Secondly, it compares the two values. And lastly, if the second values is greater than the first, it automatically adds #lie to the tweet text. If the second value is equal or lesser the initial value, #true is added to the tweet. The hashtags are not displayed at this moment and the tweet must be made public in order to get the results.
7. The button "Tweet!" sends the tweet.

Installation setup and exhibits

ToD was exhibited in two occasions. The first exhibit was in April 2013 at the Hunt Library for the 4th CRDM Research Symposium[49] (figure 7) and later in May 2014 at the Interface Interference Smartphone Art Show[50] (figure 10) at the Carrack Modern Art Gallery.

[49] http://crdm.chass.ncsu.edu/sites/symposium/2013

The final setup of the ToD hardware, the software application, and the functionality of the interface resulted from planning, trials and errors of circuit mounting, and program writing. As described in the building process, the setup of the installation changed significantly between the first and second exhibit. The changes were necessary for technical, conceptual and poetical reasons.

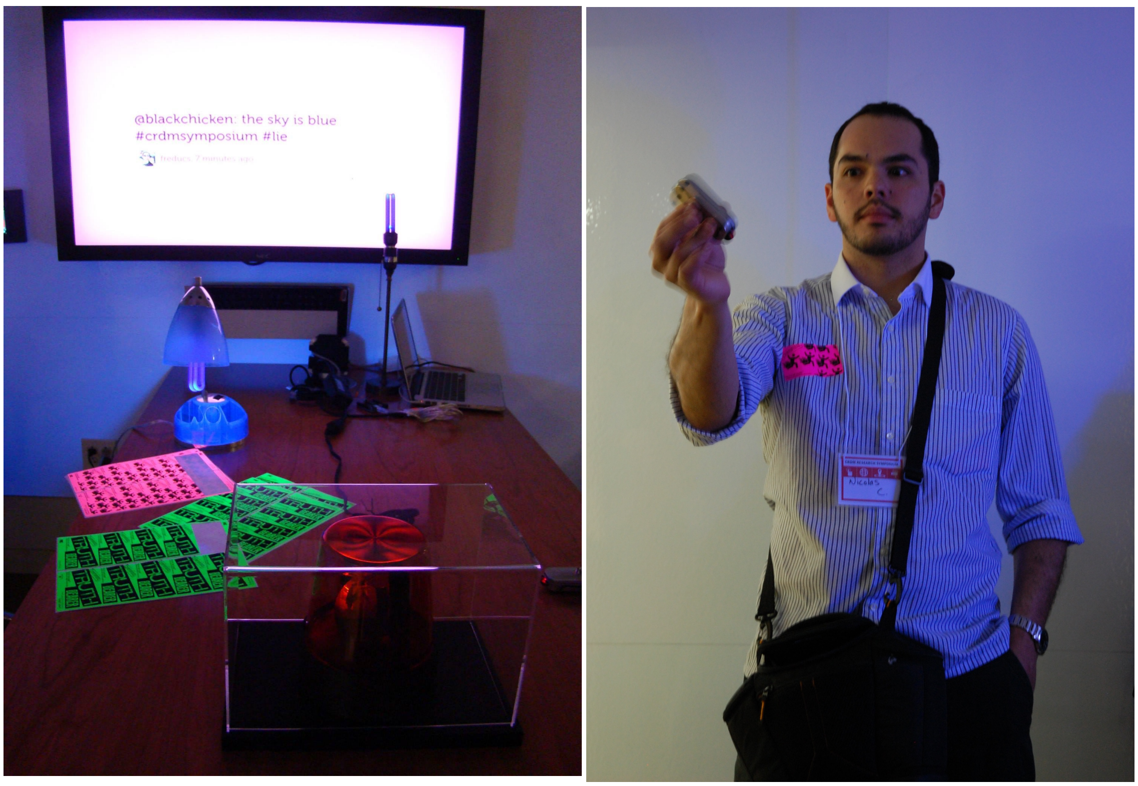

Figure 7: On the left, the setup of the Truth or Dare installation at the 2013 4^{th} CRDM Symposium. On the right, a user holds the ioio board and participates in the installation.

The ToD installation was composed by four hardware platforms. One is the ioio board which processes the physiological data collected by the sensor. As shown on the previous figures, the ioio board measures 2,5 X 4,5 centimeters, is battery operated and it was mounted on a tin can. The galvanic response skin sensors are attached on the surface of the tin can—where the user's skin contacts it while holding the can (figure 7). The second hardware platform is an android smartphone where the ToD app is installed. The data collected through the sensors and captured by the ioio board is transmitted via Bluetooth to the smartphone. The parameters that define whether a statement is true or false are defined in the app's program, as described in the previous section. The third platform was a screen that showed the tweets that had been marked with #lie. During the exhibit at the CRDM Symposium in 2013, I used a website[51] that hosted a Twitter visualization tool to search and display all tweets that contained #lie or #true and the official hashtag of the event (#crdmsymposium and #interff). While this tool allowed for an appealing aesthetics, it was not updated in real time and did not grant me access to the backbone of the search engine that conducted the visualization. Thus, it did not allow for any customization of the tweets presentation (figure 8). In the following exhibit I adopted a different tweet visualization, which I explain further in this section.

And finally, the fourth platform was initially composed by an Arduino connected to a beacon light. The Arduino ran a program that conducted an online search on Twitter for the hashtag #lie in tweets sent out by the user. The program ran in loop and was constantly monitoring online activity on Twitter. When a tweet that contained the term #lie was found it sent a digital output to the beacon light causing it to turn on for a number of seconds. To increase real-time perception of response to the participant's engagement with the installation, I included a projection of the tweets. This created greater sense of interactivity between the input of participants' actions and outputs of the

[51] http://visibletweets.com/

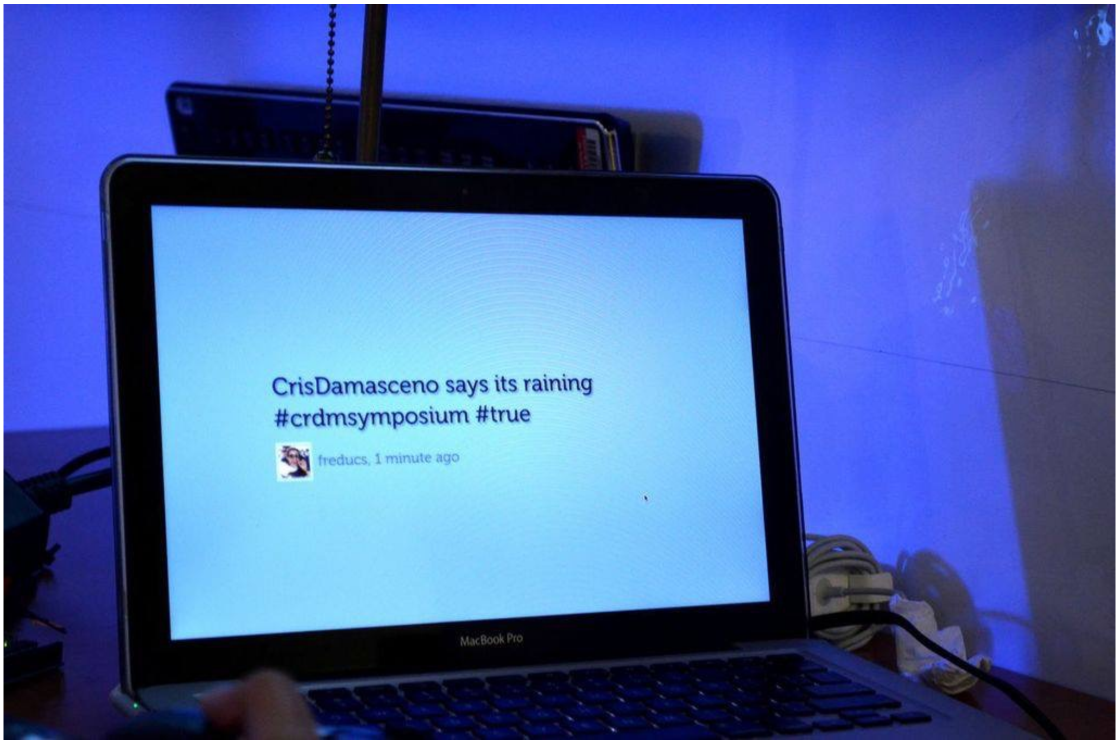

Figure 8: Tweet visualization using the Visible Tweets online tool.

installation. However, after the exhibit at the CRDM symposium, I was prompted to replace the Arduino in this part of the installation as well because the Twitter API was updated and the Twitter library for the Arduino stopped working. I replaced the Arduino with the raspberry pi.

The raspberry pi[52] is a Linux based computer in the approximate size of a credit card. While they look very similar, they are different in purpose. The raspberry pi is a fully functional computer, while the Arduino is a micro-controller, which is a single component of a computer. The Arduino can only run one program at a time but it interfaces more easily with other pieces of hardware, such as sensors. Meanwhile, the

[52] For more information on the raspberry pi see http://www.raspberrypi.org/help/what-is-a-raspberry-pi/

raspberry pi can run multiple programs simultaneously, works with a Linux operational system and allows for programs to be executed in various languages, such as C++, python, and java. The raspberry pi ran the same program as the Arduino, but now programmed in python, a very accessible programming language. The program conducted a live tweet search for #lie and #interff and when a result was found, the tweet was printed on the terminal screen (figure 10). Also, a digital output was sent to the raspberry pi board which turned the power switch on the beacon lights on.

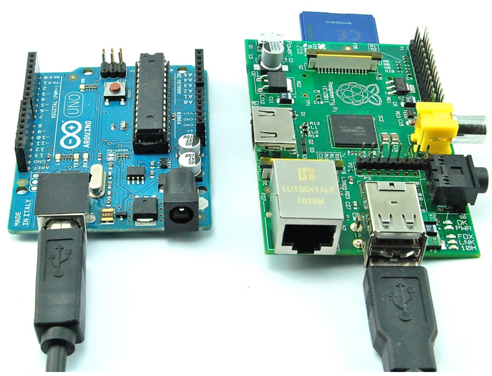

Figure 9: On the left, the Arduino UNO. On the right, the Raspberry Pi.

Figure 10: Setup of the Truth or Dare installation at the Interface Interference Smartphone Art Show at the Carrack Modern Art, Durham, North Carolina, in April and May 2014.

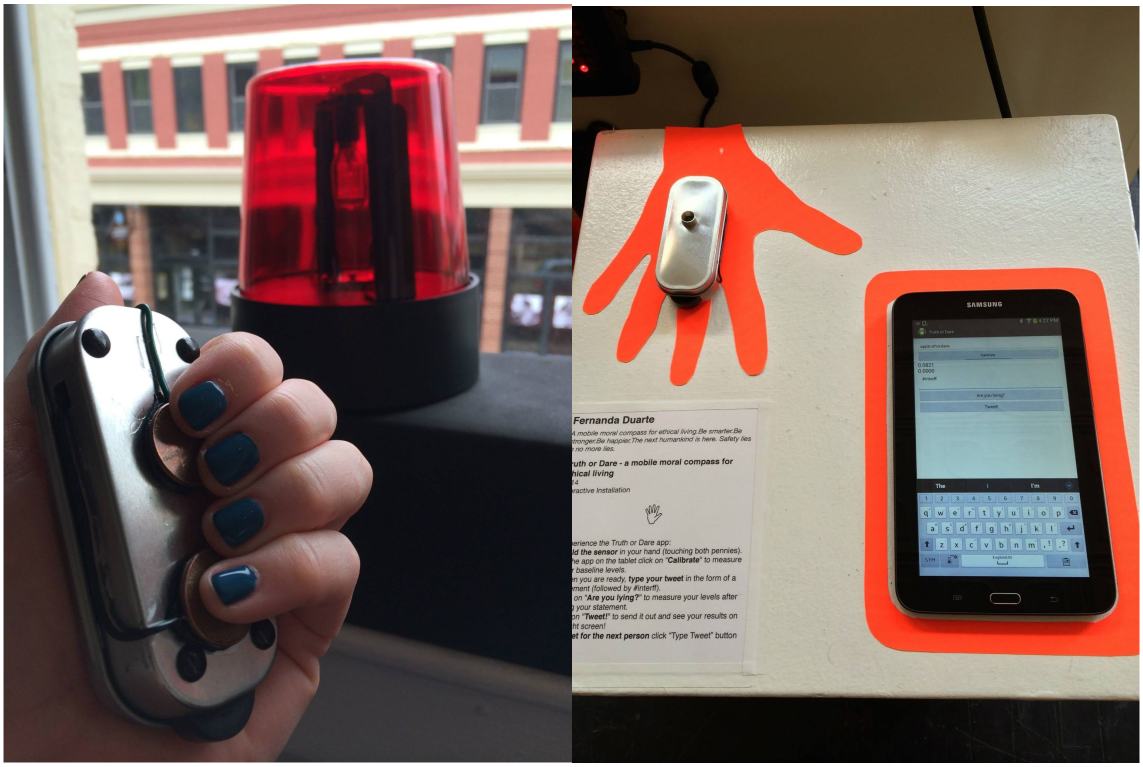

Figure 11: On the left the user holds the tin can, which contains the galvanic skin sensors (made out of wire and coins) and the ioio board. On the right, part of the display of ToD at the "Interface Interference Smartphone art show" in April, 2014, in Durham, North Carolina.

The use of the raspberry pi prompted me to combine the tweet search, the tweet visualization, and the digital output to the beacon lights in the same program. As figure 12 shows, in the second exhibit the tweet visualization was done through the raspberry pi's terminal screen. This shift allowed for every tweet to be visualized in real time and I believe it contributed to greater engagement with the installation as participants more clearly visualized their actions as required for the program's outcomes.

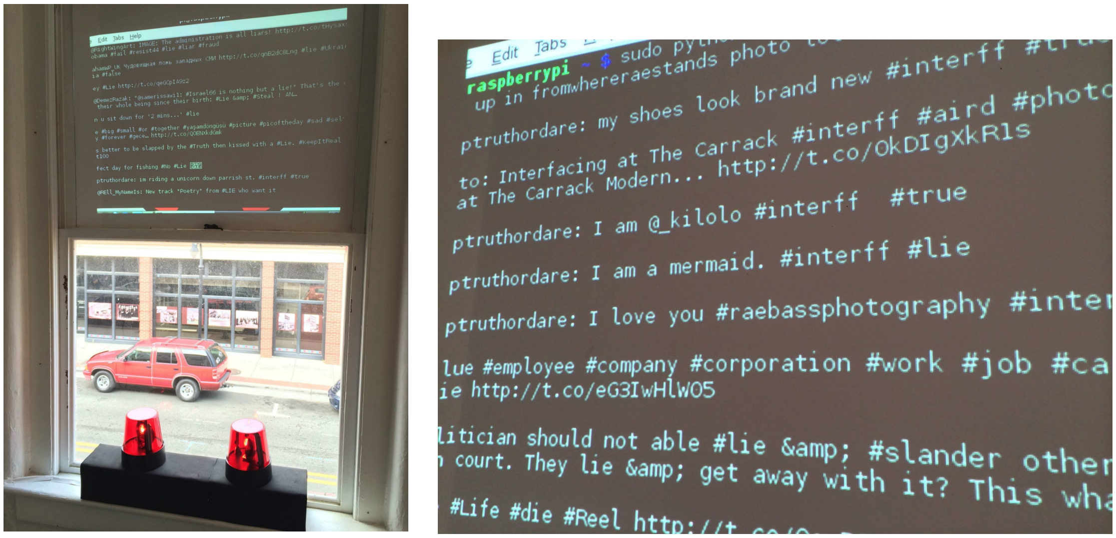

Figure 12: Tweet visualization using the Raspberry Pi terminal.

For the second exhibit I included four beacon lights and a video[53] that was projected in conjunction with the tweets. The video followed the ironic and provocative tone of the ToD. The narrative of the video is a non-linear montage of images and text that hint on the relationship between humans and technology faced with a prognosis of a future humankind optimized through machinical enhancements. By including the video in the installation I intended to call attention to our expectations and the role of technology in our self-making practices. I also wanted to situate ToD and it's ambiguous capacity to measure truthfulness in the context of emerging pervasive technologies and their agency in the creation of forms of knowledge.

Emboding truth, flesh, and code

At the first exhibit of ToD, the audience at the Hunt Library at NC State was mostly composed by academics in the field of Humanities and Social Sciences that had come to

[53] Available at https://www.youtube.com/watch?v=eX03jC1Auk0

take part of the CRDM symposium about emerging genres, forms, and narratives in the digital age. The interactions of the audience with the ToD installation pointed to diverse understandings of the social role of technology and the expectations the audience has on what technology can do. The symposium program contained a description of ToD and explained the premises of biofeedback measures in a lie detector. As I was asked to explain the inner workings of the app and the hardware, the visitors' reactions were either of incredulity of the premise, bewilderment with the concept, or fascination with the possibilities of finally unveiling secrets. I describe some of these situations next.

During the exhibit, a professor walked in the room accompanied by another university staff member. "This is a project by one of the CRDM students," he introduced her to the installation and then to me. He proceeded to explain that the project was part of my dissertation research and that I had built a lie detector. As the words left his mouth, her facial expression changed to surprise and apprehension. Her body language screamed intimidation. I stepped in and explained the conceptual premises of the project, and that my goal was not to build a mobile (and more efficient) lie detector. I said I was coming from a critical perspective, and that by building this interactive installation I was interested in experiencing with the making of digital technology and the construction of forms of knowledge through digital materiality. I pondered that the thresholds of "truthfulness" to alert for the occurrence of lies were setup in the code of the app, that they had been based on previous research on usability of lie detectors and they also had been somewhat defined by arbitrary choices. "Ok, but does it work?", she anxiously asked me. In my mind, I had Bruno Latour's (2002) discussion of morality and technology[54] conflicted with her

[54] Latour, B. (2002). Morality and Technology. The end of means. *Theory, Culture & Society*, December 2002; vol. 19, 5-6: pp. 247-260.

expectations of ToD as an autonomous instrument to measure truth. I had to ask myself that same question. Does ToD work? ToD does work in the sense that the program executes the parameters that are predefined. It does so promptly and consistently every time the application is executed. But the programmatic efficiency is only one aspect of the question. Behind "does it work?" lays a second question "how does it work?" and a desire to master the technology as a mean to reach an end (discover the truth). When the visitor asked me this question, her expectations did not relate to the workings of the ToD computing machine, but to the purpose of ToD as an effective measure for truthfulness. In which forms does ToD produce moral parameters? I resort to Bruno Latour (2002) to answer this question and argue that ToD does produce morality, but not according to the instrumental expectation of this—and many other—visitors.

Latour (2002) fights the separation between the realm of technologies, perceived as means to an end, and morality, as pertaining to the realm of humanity. While other sociologists reinforce the idea of moral development as essentially human, enacted through the emancipation from technologies, Latour (2002) argues that moralities and technologies are indissolubly mingled.

> Morality is no more human than technology, in the sense that it would originate from an already constituted human who would be master of itself as well as of the universe. Let us just say that it traverses the world and, like technology, that it engenders in its wake forms of humanity, forms of subjectivity, modes of objectification, various types of attachment" (p. 254).

Technologies and morality are entrenched in a regime of enunciation; they constitute modes of existence as they produce form of exploring existence. As a technology, ToD is not a probe tool that gathers objective evidence and based on numeric parameters seals one statement as true or false. Its morality is not exercised objectively and is not manifested obviously. It is exercised through distributive agency, sustained by a computing form of knowledge that organizes ways to know and represent reality. So, the moral judgment that ToD enacts does not occur when it assigns #lie to a tweet when the program collects data that are out of the range for truthfulness. Rather, it occurs as ToD embodies a moral philosophy of computing code as a form of knowledge, as a mode of existence and of being in the world that is historically situated in the contemporary age.

At the many times I was asked "does it work?", my response was not this theoretical digression on technology and morality. Instead, I responded with another question, "do you want to give it a try?", as a strategy to get visitors to interact with ToD and come up with their own answers to if ToD worked or not.

It was also common that visitors interacted with ToD as if they were testing a prototype of a new gadget. They would tweet statements they already knew to be true or false to verify if ToD would correctly assess them. In one occasion, a visitor tweeted "The sky is blue," which was automatically tagged with #lie. What followed that result was a series of speculations by the visitor as an attempt to understand why ToD had verified that statement as a lie. Had she not believed in the truthfulness of the statement enough while typing it? Had her body revealed her true beliefs about the color of the sky and exposed a true knowledge of which she wasn't aware? After exploring these possibilities, the conclusion she came to was, "Oh, it's been rainy today and it's so gray outside. In fact, today the sky is not blue." ToD acted as a proxy to validate a version of truth that was afterwards reinvented by her. By proposing this justification to the outcome, she rearticulated the antagonism of discourses, actions, and technologies and rendered her own fiction, her own version of truth. Interactions such as this demonstrate that ToD functions as a lie detector not in the sense that it tells lies from truths, but as a Foucauldian apparatus that materializes "games of truth," that is, strategies for fabrication of truth. By either fulfilling or conflicting with the expectations of users, the observed interactions with ToD demonstrated that whatever truth is, it is not defined by the parameters of the app but on the basis of practices. It happened in the negotiation between the users and the ToD installation, as users would change their discourses, and reinterpret the ToD's output in ways that were coherent and convenient to that social situation. Within the ToD installation, morality is rooted in the arrangement of discourses, affects and practices shared among the users and computing technologies as a form of knowledge.

In fact, the full development of the interactive system with data visualization, micro-controllers, sensors, and app might not have been required for ToD to enact a "game of truth." A mock hardware setup and a simulation of an app could have sufficed to sell the premise of a biometrics lie detector. The actual collection of physiological data transcoded into digital data was not what defined truthfulness in ToD. Regardless of ToD's assessment of statements as true or false, users would every time reinvent the meaning of the statement, rearticulate the ambiguity of the situation and end up themselves exercising a personal judgment of truthfulness of statements. Absurd tweets, such as "Steve Wiley says unicorns are real #crdmsymposium #true" or "I am a jelly doughnut #lie #interff" express unrealistic possibilities and can be interpreted as a strategy to test ToD's capacity to assess truth. But at the same time, they evince a ludic relationship between users and ToD as the absurdity of the inputs and outputs turns the interaction into gameplay. This relationship marks a shift form ToD as a goal-oriented system assess truth to an open ended arrangement of fictional arguments. These surrealistic tweets are merely another facet of an also surrealistic expectation of outsourcing moral judgment to a lie detector machine.

ToD takes shape in ambiguity. It was built based on functional premises of lie detectors. However, it mocks them while proposing to self validate all of the tweets. It intimidates gullible users who would rather play it safe and not take the chances to be caught on a lie. At the same time, it awakens the inquisitive mind of others who tweet about unicorns and other non-existing creatures to test if the device is really "functional." A web of fake lies takes over ToD's Twitter account, as users decide to take the moral judgment back on their own hands. It prompts continuous tweeting, as heavy users repetitively try to beat the machine and take control over the moments they get a #true or #lie. The data collected by the sensors is not intentionally given by the users, as they don't always know which are the mechanisms that constitute that system. In this sense there is a clear shift of the subject position as the one (no longer) in control of the experience.

In the process of making ToD, I navigated a fine line between making a functional application and one that disrupted the familiarity in which we engage with mobile apps and provoked reflexive thinking about our interactions with pervasive technologies. My firm disbelief on the premise of biofeedback as a measure for emotional response and, furthermore, for moral judgment prevented me into falling into the trap of technology fascination. However, at the same time, ToD needed to be consistently responsive—not in terms of assigning truthfulness, but in ways that provided consistent and coherent parameters of feedback, thus creating some level of empathy with users.

The ways in which digital materiality is organized—in the underlying cause-effect logic in which input/output sensors are built, in the syntax of programming language—is interweaved with how quantified emotional response is made analogous to truthfulness.[55] At the same time in which I conformed to the boundaries of the syntax and the lexicon of the programming language to make an operable installation, I was faced with situations that challenged the role of analog sensors as probes of "raw data" and of the code as its objective translator. The challenge with the inconsistent values of the analog sensor translated into digital data demonstrated the need of creative interference to produce the illusion of direct correlation between physical and digital realms. The functions that constitute the syntax of the programming language (in the case of ToD, the "smooth" function was key to average the erratic data) are productive creators of data, not noise reductors—as the Shannon and Weaver (1963) model would argue. These situations reminded me that this making practice was not setup as a goal-oriented project, but a creative, speculative experiment. As Kittler (2008) reminds us "the program will suddenly run when the programmer's head is emptied of words" (p. 46). These situations prompted me to engage with ToD in ways to acknowledge the distributive agency shared among pieces of hardware, electric current, rationality and senses. This variation of data sometimes would occur due to unexpected elements in the environment (as described previously, inconsistent voltage introduces noise to electronic circuits), changes in the materiality of the sensor (as many users hold on to the sensors, the surface of contact requires cleaning to recover full electric conduction), and to clash of information protocols

[55] In chapters 4 and 5 I discuss further how the appropriation of pervasive computing produces practices of self-making and of self care that are deeply entrenched into the computational logic of big data, also demonstrated by my observations of the Quantified Self movement's discussion forum.

that regulate established norms of conduct in social media (the excessive number of tweets gave the ToD Twitter account a spammer profile which prompted it to be sometimes blocked). And finally, these situations compelled a reflection of the embodiment of flesh, code and truth in co-constitutive terms, “entwined within the physical structures of technological media and bodily systems” (Gane & Beer, 2008, p. 43).

The interactive arrangement proposed by ToD advocates against essentialist oppositions between the human and machine, idealism and materialism, and reflected the deconstruction of said “natural” and “artificial” entities. By distributing agency and triggering discourses through the process of transcoding analog into digital data, I exercised Donna Haraway’s (1991) premise that we are all contingently materialistic political constituted selves (let them be of gender, race, biology, informatics...). Coming from cybernetics studies, Haraway (1991) acknowledges coding as a social practice that has surpassed the world of informatics and linguistics. By distributing the agency of the conversation to a set of nonhuman agents (the ToD app withholds the code parameters for truthfulness), I aimed to call attention to our human condition as one that is “a political exercise of the interrelationship between science, technology, and power as a matrix of complex dominations” (Haraway, 1991, p. 165) built upon otherness and difference. Anna Munster (2006) expands on this matter when she says that “new media theory needs to consider embodiment through the sensory disruptions and reconfigurations that virtuality creates. Virtual realities and digital embodiment must think of the physical as other than merely a vessel for consciousness” (p.16). She continues,

> Pairing back older notions of the digital as the pathway to the virtual in which we were promised better and more complete access to either the sensorium or

> hyperreality will leave room to acknowledge the contribution of our corporeal capacities to technological interaction. (Munster, 2006, p.17)

In chapter four I discuss further how the production of truth in ToD functions as a is tied to the production of a sense of self knowledge as a strategy to regain control over a sense of self.

In the following chapter, I expand on how the interactions with ToD relate to forms of technology appropriation by followers of the Quantified Self movement. Quantified Self followers keep track of their physiological performances through pervasive computing technologies, such as wearables and sensors. They create data visualizations that render legible a map of their biological bodies. In the construction of the ToD experiment, I also mapped users' physiology and transcoded their biology into data, which was then arranged into programmed parameters for moral judgment. Chapter 3 addresses the following research question: "How are embodied spaces produced through the appropriation of pervasive computing technologies?". To answer, I discuss how the deployment of large databases and sentient infrastructure not only stretches the scalability of the information network into macro (i.e., predictive models based on big data) and micro (i.e., personal data maps an individual's physiology) levels but also creates forms of spatial knowledge intrinsically tied to the modus operandi of data mining.

CHAPTER THREE

Data mining and hybrid spaces

"Revolutions in science have often been preceded by revolutions in measurement." Sinan Aral[56]

In the fall of 2013, a discussion thread caught my attention on the Quantified Self forum:

> John North: I want to start tracking my heart rate while sleeping, and was wondering if you have any equipment to suggest. I have a pulse oxymeter (which also tracks heart rate) with memory, but having that device on my finger while sleeping is inconvenient. One option is using a chest strap together with this receiver[57] and this app,[58] but I'd be interested in knowing about alternatives. A wristband instead of a chest strap would be great.[59]

John's post was followed by a series of reviews of apps to measure heart rate variation and detailed description of methods and possible correlation with other variables. Among those, Frederic responded by sharing the results of an ongoing self experiment[60] in which he studies variables and causes of sleep disorders. He tracked his sleep over 19 nights using an app called SweetBeat[61] and processed the data using a heart

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[56] Retrieved from http://www.economist.com/node/15557443 in June 2015.
[57] http://quantifiedself.com/guide/tools/431/ithlete
[58] http://itunes.apple.com/us/app/ithlete-hrm/id381116330?mt=8
[59] Available at https://forum.quantifiedself.com/thread-how-to-measure-heart-rate-while-sleeping. Retrieved in March 2015.
[60] The user Frederic links his website in his post to the Quantified Self forum, where he keeps his experiments data and results. The experiment he cites on his post is available at http://www.scanx.org/fredqs/experiments/page13/page13.html
[61] http://www.sweetwaterhrv.com/

rate variability analysis software called KubiosHRV. He compared his data with previous studies published about sleep disorder and chronic fatigue syndrome to identify the numeric parameters that defined the disorder and contrast how his personal data stood in comparison to the baseline of sleep disorder. Frederic's website contains a list of other experiments using self-tracking tools and a detailed description of his methods (figure 13). Besides the apps mentioned in his response to the user John North, Frederic manages his sleep activity with the Zeo Sleep manager (an electroencephalography headband that measures brain waves and identifies sleeps stages), an app called Sleep Cycle (uses an accelerometer to measure movement while sleeping), the Withings devices (to track body weight and blood pressure), and a couple other applications to track daily workouts.

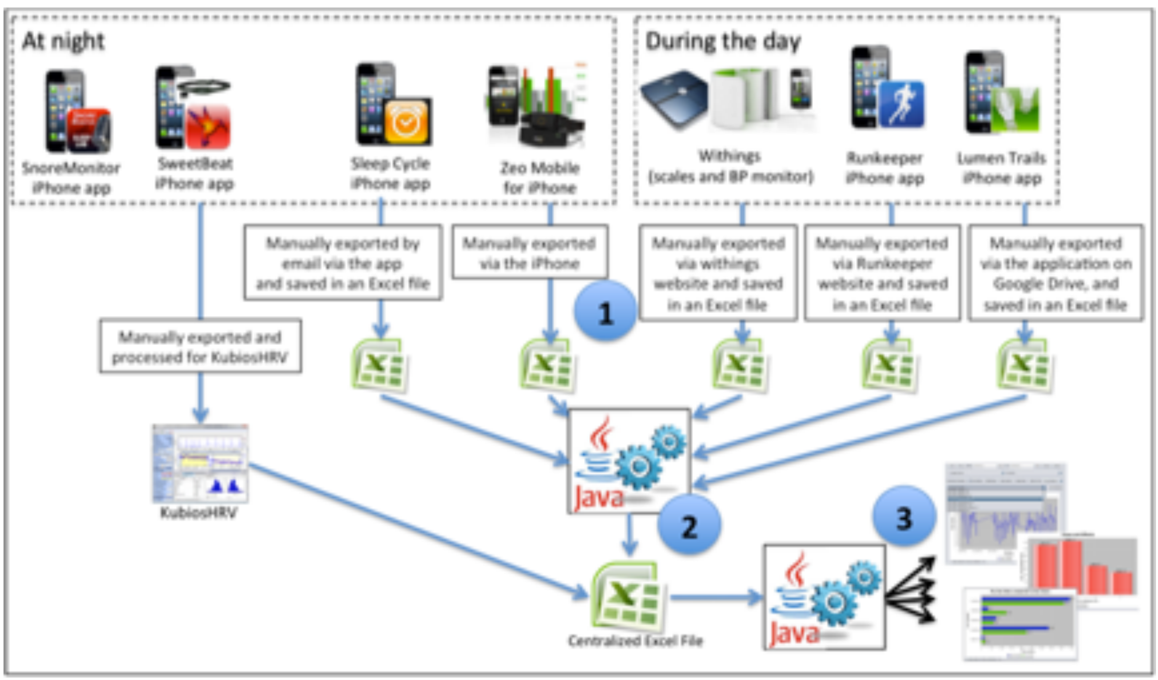

Figure 13: Data gathering process, from tracking to analysis/visualization phases designed by Frederic, a user of the Quantified Self forum, to describe his sleep tracking methods. Available at http://www.scanx.org/fredqs/main/sleepgatheringprocess.html

Frederic collects data on a daily basis and keeps track of 40 variables. All the data is exported into excel files and processed on a java program he wrote, which outputs charts that display the results of the interaction of the different sets of data based on correlations he designed. Through these correlations he can identify trends and redundant patterns in a particular timeframe while building what Frederic calls his "sleep architecture." The complex, automated and integrated wearable devices gather data continuously in a non-intrusive way and feed a growing personal "big data" database. The goal of this personal *mise-en-abyme* surveillance system (in which Frederic is the thing surveilled while relying on the data to make sense of himself) is to gather as much data as possible about everything at all times. Later, through automated data analytics provided by applications, Frederic establishes correlations to identify trends in his body's performance (see step 3 showed in figure 13). Through big data collection and processing, Frederic maps the internal space of his body.

Big data does not refer only to the large volume of the data set and the tools to process it but marks a radical shift in how computational data is being used as a paradigm for knowledge production. It rests on the maximization of computing capacities to collect, aggregate and correlate continuously growing sets of data. It relies on the capacity of algorithms to parse out raw numeric data to identify patters in order to establish trends and preconize scenarios. Frederic's use of data mining[62] to continuously collect 40 data variables allowed him to establish diverse correlations between the duration of each sleep cycle, the intensity of light, wake up time, nutritional information etc. The larger the sample and the longer the historical progression, the more reliable and

[62] Data mining is the automated process by which data is gathered and parsed out by computing algorithms.

generalizable the forecasts are, for how Frederic's body performs. Ultimately, big data emerges as "a system of knowledge that is already changing the objects of knowledge, while also having the power to inform how we understand human networks and community" (Boyd & Crawford, 2012, p. 665). It brings profound changes to how we think and do social research through computational data, not only because big data offers an unprecedented quantity of data at the level of the individual scalable and generalizable to the level of populations. Mostly because it introduces big data mining as an episteme for knowledge construction.

> Big Data reframes key questions about the constitution of knowledge, the process of research, how we should engage with information, and the nature and the categorization of reality. Just as Du Gay and Pryke (2002) note that "accounting tools ... do not simply aid the measurement of economic activity, they shape the reality they measure" (pp. 12-23), so Big Data stakes out new terrains of objects, methods of knowing, and definitions of social life (Boyd & Crawford, 2012, p. 665).

Frederic's account is one of many in the community of self-trackers who gather personal data and build an archive of physiological logs to better understand themselves and how their bodies operate. The correlations established by Frederic and other users articulate physiological information with environmental conditions (i.e., level of CO_2 in the bedroom and quality of sleep), behavior (i.e., nutritional intake and level of energy) cognition and decision-making (i.e., measures of level of stress). By monitoring these variables, they create personal databases and through correlations and visualizations they create representations of their bodies, built upon their physiologies transcoded into digital data, self-awareness and social norms.

As discussed in the first chapter, the Internet of Things is established through the implementation of networked sensing technologies such as laser, bluetooth, GPS and RFID embedded into architectural spaces and objects (Weiser, 1991, Ashton, 2009, Dourish, P., & Bell, G., 2011, Greenwold, 2003, Goggin, 2011, 2014). In this chapter I acknowledge how the underlying logics of big data that animates the IoT produces a novel way to collect and process data that is determinant to spatial practices.

As exemplified by Frederic's case, the development and appropriation of sensor technologies not only intermeshed the analog-atomic and the digital-bit worlds, but intensified the ongoing automated processes of data collection. Sensors are always on sentient mode, accumulating big-data about weather, traffic flux in a city, and Frederic's sleep patterns. As the network of sensors implements a large-scale data-territory of urban physical spaces, big data also produces micro scale territories of bodies. By appropriating these sensors, Quantified Self users keep track of their unseen physiology and create big data visualizations that render legible a map of their biological bodies. In the construction of the Truth or Dare experiment, I also mapped users' physiology and transcoded their biology into data which was then arranged into programmed parameters for moral judgment. The deployment of large databases and sentient infrastructure not only stretched the scalability of the IoT network into macro (i.e., global mobility patterns) and micro (i.e., individual physiology) levels but also creates forms of spatial knowledge intrinsically tied to the modus operandi of data mining.

The question of how spatial practices are created through emerging computing technologies has been intensively discussed in the field of mobility studies (Sheller & Urry, 2006, Creswell, 2002, 2010, 2010a, Benford & Giannachi, 2011, de Souza e Silva, 2006, Dourish, 2006, Farman, 2012, Gordon, 2008). From a mobile communication research perspective, Adriana de Souza e Silva (2006) has discussed how the appropriation of location-aware technologies such as GPS in smartphones has fostered the creation of hybrid spaces. According to de Souza e Silva (2006), hybrid spaces are created when mobile technologies act as an interface to navigate physical space. Previously enacted cyberspaces are complicated with the mobile aspect of location-aware technologies and, in consequence, physical spaces are reconfigured through informational layers (i.e., Foursquare and its check-in function meshes the informational layer with a physical location).

This chapter expands on the notion of hybrid space to acknowledge big data mining as the underlying logics that sustain the multiple spatial scales in the IoT. I argue that the dynamics of data mining, correlation, and analysis are key aspects in the construction of hybrid spaces in the IoT. I address the following research question: How are embodied spaces produced through the appropriation of pervasive computing technologies? To do so, I first define big data and its dynamics of data mining, data correlation, and analysis. To understand how the Internet of Things operates in integrated scales of topologies (i.e., from smart cities to nano-technologies), I argue that it is necessary to approach big data mining as an epistemological code for spatial knowledge. I discuss how the implementation of the Internet of Things, sustained by the underlying logics of big data, traces the corporeal performance and turns the biological body into a representational space to be mapped (i.e., a representation of what is a healthy body or a truth teller). I conclude this chapter with an analysis of spatial topologies in the IoT based on the use of self-tracking tools by followers of the Quantified-Self movement.

The logics of big data

The term “big data” can be deceiving by implying that big data is merely defined by its size. The large volume is an expected consequence of the computerization of culture as digital media processing permeates many of our daily activities, from governmental processes to scientific research and social interaction. Nonetheless, big data is only described in part by the ever-increasing size of databases. The U.S. census, financial markets and weather forecast are examples of large databases that have been established for decades. Harvey Miller (2010) reminds us that despite of their volume the knowledge that can be produced based on these databases is limited due to how the data has been collected, stored and processed. The U.S. census, for example, collects demographic information every ten years by having individuals respond to a predefined questionnaire that once created cannot be edited until the next collection period. The data set is rigid, the collection method is primitive and in consequence, the output is coarse in resolution (Kitchin, 2014). The database that results from the census is large, but it is as large as the temporality of its collection. It is static and hierarchical and functions as a backup archive for liability reasons. It is organized in neat tables that respect the rigid hierarchy of the collection forms. It is self contained and encapsulated by the limitations of the data mart physical storage capacity. The purpose of the census database ends on itself as it can only provide answers to the questions that were contemplated in the data collection form.

Differently, big data is a dynamic flow of diverse, flexible, fine-grained, relational data (Kitchin, 2014). I explain further. Consider the digital rich environment we live in. As we go by our daily activities, data is consistently streamed. We access our Gmail accounts, run searches, browse Amazon.com and watch vlogs on You Tube. Meanwhile, Google Analytics algorithms are extracting all the metadata (including that email you just sent out) to establish correlations within your digital history, and within all the other users in Googleverse, to identify patterns of communication. The identifiable patterns will, for example, inform targeted advertising (Google's AdSense) and tailor other marketing services. Add to that mix all other sources of data mining through smart devices and sensors that model the Internet of Things. Then we are faced with analog data, such as air quality and individuals' heart rates, which is transcoded into a flux of metadata that feeds into a perpetual motion machine of algorithmic analysis.

One main distinction between the large data sets before big data and the current ones is the level and the architecture of metadata storage. In the first large data sets (i.e., the U.S. census) metadata served a unique purpose of categorization for archiving data through content. The process of assigning metadata categories is itself interpretative and requires human input to enter and extract the information. These large data sets are stored in a structured database management environment (data marts), which functions as a depository. In order to optimize data analysis, the data is pre-categorized at the point of entry. The level of metadata is kept relatively simple and low, enough only to conduct queries and aggregation. In contrast, big data is metadata rich, as it relies almost exclusively on this layer of information to identify statistical trends in the body of data (Miller, 2010). Big data is collected and kept unstructured and schemaless to enable customizable data analysis and processing. Due to the level of complexity, it can only be processed through "actionable intelligence;" that is, no human brain is able to analyze it and the process must be outsourced to algorithms. Big data requires a different architecture of storage than the data mart. James Dixon, the CEO of Pentaho is calling this architecture a "data lake:"

> If you think of a datamart as a store of bottled water—cleansed and packaged and structured for easy consumption—the data lake is a large body of water in a more natural state. The contents of the data lake stream in from a source to fill the lake, and various users of the lake can come to examine, dive in, or take samples.[63]

Big data is vital matter of numeric discretion and modular scalability, being constantly compared and correlated with other data samples. It is cloud based and is continuously being collected by automated data mining, most of the time regardless of human intention and awareness. As explained in the example of how Frederic learns about his sleep pattern, the data collected by the wearable sensors is discrete, numeric and always unfinished, as it is constantly being expanded. While the data collection in the large datasets of census is systematically surveying targeted objects (for example, the level of education or household income, which are then defined as either binary or as in a threshold), data mining is collecting all data possible, at all times which can later be parsed out by data analytics and organized into predictive trends. Frederic's personal big data is setup as floating variables, which can be cross-compared to create correlations that he had not even anticipated or knew to look for. What big data aspires for is the predictive power to arrive at correlations that otherwise could not even be intuitively

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[63] Available at https://jamesdixon.wordpress.com/2010/10/14/pentaho-hadoop-and-data-lakes/

imagined. In this aspect, Mark Andrejevic and Kelly Gates (2014) argue that the potential of usability for any data is speculative because it cannot be assessed if not in comparison with other data sets. Data gathered today might only become relevant in the future, when newer data is collected and a pattern is identified. And for this reason, it is justifiable to collect all data, at all times, aiming for "total information awareness" even when some data sets initially do not seem relevant.[64] In summary, big data emerges in the moment that strategies of sense-making through algorithmic data analytics can be applied to the growing data troves.

Big data can be modulated to provide information on a micro scale of the individual (Frederic's individual sleep patterns) or integrated with similar databases created by other users to generate correlations in the scale of a population (average American male sleep patterns). The correlation in a large scale of the population is critical to the creation of parameters of "good sleep" and marks an epistemology of data-driven science that leans toward inductive reasoning. Data correlation is used to form hypothesis before developing a deductive approach; "rather than testing a theory by analyzing relevant data, new data analytics seek to gain insights 'born from the data'" (Kitchin, 2014, p. 2). Digital data is collected, correlated and manipulated as a rhetorical enactment, and an object of knowledge, funded upon a digital episteme (Maddalena, 2014).

Jeremy Packer (2013) reminds us that digital media is foremost epistemological because it "…predicts, collects, assesses, guides, directs, processes, opens, shuts, invades, experiments, and expands every data-producing moment we are networked OR un-

[64] These dynamics are discussed by Andrejevic and Gates (2014) as big data surveillance. I will expand on this issue on chapter 5, when I discuss the power relations in pervasive computing.

networked—absence of data is itself meaningful data" (p. 295). The epistemological characteristic Packer (2013) brings up is tied to the discussion of episteme presented by Michel Foucault (1970, 1980). In the *Order of Things*, episteme is defined as the unconscious structures underlying the production of scientific knowledge of an era. Even though Foucault initially circumscribes episteme to the level of discourse, he later (Foucault, 1980) reviews it as inscribed within a larger *apparatus* composed by discursive and non-discursive forces of power-knowledge and subjectification. That is so because the understanding of power as a networked formation acknowledges that power is not constricted to a vector of discursive formation and is extensive to institutional practices, regulations, laws and morality. The notion of apparatus articulates together forms of production of knowledge and subjects with social practices as (institutional) technologies of power. "The episteme is the 'apparatus' which makes possible the separation, not of the true from the false, but of what may from what may not be characterized as scientific" (Foucault, 1980, p. 197). It traverses textual expression and social practices in the establishment of institutions, scientific discourses and policies and establishes a power-knowledge system. Therefore, the act of knowing and the creation of objects of knowledge are mediated by the discursive and material assemblages that shape the *apparatus* while also forming the subjects of knowledge.

By describing digital media through its epistemological power, Packer (2013) calls attention to the ways in which the digital media *apparatuses* form conditions for knowledge production and validation. The logics of big data follow the epistemic action of digital data, in which new strategies of knowledge construction and of creating a sense of self are organized through the collection, modularity and correlation of aggregated data. In this sense, big data mining creates a shift in knowledge production and scientific discovery from a paradigm of semantics to a paradigm of pragmatics, "big data mining privileges correlation and prediction over explanation and comprehension (Andrejevic and Gates, 2014. p.186). Based on data correlation, it is possible to identify *what* is happening in the data set, however, the nature of statistical correlations does not demonstrate contextual information that explains *why* they are happening. Andrejevic and Gates (2014) explain the meta-function of big data through the lens of Slavoj Zizek's (2001) concept of the Symbolic Real, that is "the signifier reduced to a senseless formula, like the quantum physics formulae which can no longer be translated back into—or related to—the everyday experience of our life-world (p.94)." The complexity of big data mining is such that its dynamics cannot be apprehended as a whole and must be condensed into a mathematical equation. Once this equation is formulated, it can only be put into application. We can substitute the variables for different values and calculate the outputs but not fully recreate the steps that generated the outcome, not predict future possibilities if not through the formulae. All that is left is a mutual acceptance that the formulation is correct. In this sense, data correlation scrutinizes the meta level of data to establish the communication patterns that resulted in data generation. For Jeremy Packer (2013), meta-data is a rhetorical statement of communicative action by which data mining correlations build media content primarily as effects. Selfies and Foursquare check-ins are good examples of meta-data acting while effect-as-content. While traditional photography relies on visual content to communicate rhetorical expression, selfies, at the rate of one million new pictures per day,[65] are visually similar in

[65] http://stylecaster.com/selfies-infographic/

composition (stretched out arm/selfie stick points the camera to the face of the photographer while she looks into the lens). The rhetorical expression in selfies is thus not on the content of the image, but on the meta-data of the picture-taking activity: geolocation, time, use of hashtags. In a similar fashion, the check-in function of Foursquare is focused on creating a spatial-temporal stamp for meta-data, to register where you were at what time, not an in-depth analysis of your experience. Media processes overrule the media object. Matthew Fueller (2005) reiterates the argument:

> a particular packet, unlike a container among the traffic rumbling past by the way, is nothing outside of the specific protocol and infrastructure it conforms to. Its strictly technological conditions of effectuation are entirely coincident with its composition. This is not a condition of all media, nor all modern media, but it is something peculiar to digital media (Fueller, 2005, p. 127).

The *modus operandi* of big data is defined in the interplay between sentient, autonomous data collection and algorithmic analysis. The "predictive power" of statistical correlations is taken to an extreme by business and marketing research (Kitchin, 2014) as heuristics for knowledge construction (Anderson, 2008, Clark, 2013, Siegel, 2013). Such approach is named "new empiricism" by Kitchin (2014). It is heavily positivist and founded on the premise that data correlation trumps every other form of knowledge production. Chris Anderson (2008), an advocate of "new empiricism" caused a big commotion when he published a piece on *Wired Magazine* claiming that big data marks the "end of theory," because

> (...) correlation is enough. (...) we can throw the numbers into the biggest computing clusters the world has ever seen and let statistical algorithms find

> patterns where science cannot (...) Correlation supersedes causation, and science can advance even without coherent models, unified theories, or really any mechanistic explanation at all (...) With enough data, the number speaks for themselves.[66]

Anderson (2008) is not the only voice advocating for an approach of predictive analytics as basis for a scientific model. Clark (2013) and Siegel (2013) also see big data as a definitive strategy to capture the senseable reality with totalizing resolution, free of human bias and decoded in forms of data visualization. Predictive analytics is informative to some areas of research (for example, marketing research by Amazon.com uses statistics to build a system of product recommendation). But it is not sufficient to address qualitative research that requires social context information. And even in the case in which predictive analysis provides meaningful information, the numbers do not speak for themselves. Big data is not self-explanatory and at some point of the analysis will require some sort of interpretative effort. Rob Kitchin (2014), dana boyd and Kate Crawford (2012) also call attention to the dangers of this "new empiricism" approach. The myth that larger databases offer higher quality data enforces the notion of big data as providing access to otherwise attainable discoveries. This belief grants data mining an aura of accuracy, of "objective truth" and exhaustive representation. This myth fails to acknowledge that the numeric representation of digital data, even though disguised by the lens of quantifiable objectivity, does not exist outside of a system of representation. Data mining is part of a process of knowledge construction and, thus, one articulation of an epistemic system; but it is not an end in itself. While algorithms—exempt of contextual

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[66] Available at http://archive.wired.com/science/discoveries/magazine/16-07/pb_theory/

analysis—can execute data correlation, the epistemological interpretation of the outcome and the creation of knowledge are more complex and dependent upon social-technological relationships and philosophical-scientific frameworks.

Even though “new empiricism” is not in tune with the approach I want to construct about how the logics of big data animates the scalability of the Internet of Things; I must still acknowledge it has gained some traction specially among marketing research. However, my approach to the logics of big data dissociates from “new empiricism” although still data-driven. I recognize that the predictive potential of data mining in addition to its contextual shortcomings produce a novel way to collect and process data that is determinant to the spatiality of the IoT. Therefore, I argue that big data mining cannot be reduced to statistical analysis, as it is part of a larger epistemic system of digital media that converges multidisciplinary frameworks such as humanities and social sciences. The application of big data mining as an heuristics for digital media research requires a sensible balance between the expectations regarding what type of information data correlation can provide. Furthermore, it requires a selection of mixed methods to complement the questions that cannot be answered by predictive analytics. In this sense, the self-tracking strategies devised by Frederic—as a form of knowledge production about himself—cannot be reduced to an imposition of quantifiable parameters by technology on him. Conversely, Frederic’s sense of self, produced through self-tracking methods, is not completely ruled by him as if his sense of self were programmable and activated by command lines.[67] I the next section I propose an

[67] Although, after reading various reports of self-tracking experiments in the Quantified Self, I have noticed that there is an underlying motivation of self-exploration and a desire to gain some sort of leverage or of control over how your own body performs. I discuss this further in the next chapter.

expansion of the concept of hybrid space (de Souza e Silva, 2006) to conduct an analysis of the different scales of the Internet of Things—from the intimate space of the body to large urban spaces. The analysis places big data mining as the material organization of an epistemic system that reconfigures spatial forms of knowledge and strategies of self-making.

Topologies of hybrid spaces

Recent discussion in mobilities and locative media scholarship explain how recent spatial technologies, such as GPS and GIS, rearticulate the social construction of spaces, places, and locations (de Souza e Silva 2006; Callon, Law and Urry 2004; Gordon and de Souza e Silva 2011; Russel 1999; Sheller and Urry 2006; Silverstone and Sujon 2005). From the standard car-navigation GPS device to location-based social networks such as Foursquare, applications of location-aware technologies based on GPS and GIS allow the tracking and tracing of individuals and things through space, and tag them to geographic coordinates. These systems suggest that the spatial practice of movement is intertwined by a mesh of digital data and physical space, but also suggests a standard of spatial knowledge; a way to know the world spatially that is intrinsic to the technological protocol of big data mining. The use of self-tracking technologies by followers of the Quantified Self movement, for example, demonstrate how pervasive computing technologies are able to collect, quantify and build representations of the physiological performance of the body (i.e., how many calories a user "burns" while exercising). While GPS technologies and surveillance cameras map the physical space of geolocations and how things move across it, pervasive technologies map the space of the body and how the body performs *in* its own skin to identify trends and establish patterns of normativity.

The inclusion of sensor networks in urban spaces, homes, objects and our biological bodies creates hybrid spaces (de Souza e Silva, 2006) of multiple scales. Hybrid spaces are defined by Adriana de Souza e Silva (2006) as “mobile spaces, created by the constant movement of users who carry portable devices continuously connected to the Internet and to other users” (p. 262). de Souza e Silva explains that a hybrid space is different from mixed, augmented, and virtual reality because it is tied to the use of mobile technologies as social devices in ways that merge borders between physical and digital spaces. Digital spaces are online environments that were previously confined in what was conceptualized as cyberspaces. Mobile interfaces, understood as interfaces that allow connection to the Internet while moving through physical space, are critical in the production of hybrid spaces. As mobile interfaces powered with location-aware technologies shape the perception of physical spaces, physical spaces are also enfolded by layers of digital data. One example brought by de Souza e Silva (2006) to illustrate hybrid spaces is the location-based game *BotFighters. BotFighters* was a MMORPG (massively multiplayer online role-playing game) designed to be played in an urban environment while accessing the game on the phone. It was first-person shooter game where users took on a robot persona with the objective to eliminate the other players. To achieve this goal, players had to move across physical space to engage in shooting or to participate in battles.[68] The accuracy of shots depended on the chosen weapons of choice and physical proximity to the target.

The notion of hybrid space (de Souza e Silva, 2006) is important to discussions of digital media and spatial practice because it acknowledges the interrelationship between

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[68] Initially all actions in the game were carried through SMS and later a version of the game was made available in java.

physical and digital spaces. Also because it acknowledges the role of social action to the construction of space, repositioning culture and communication in the core of technology appropriation. The game *BothFighters,* for example, is founded on the interplay between physical and digital spaces and only takes shape through collective participation; gameplay is non-existent unless at least two players engage with it. But faced with the sensor rich environment of the Internet of Things, we are now required to decentralize location-aware technologies and smartphones as a starting point of access to hybrid spaces. Geolocation data is only one of the many parameters of big data being collected through data mining. Screen-based devices, such as smartphones, are one of the tools for data visualization but are no longer the only method to build data representations. Big data mining occurs through all kinds of sensing technologies, which are now dispersed in open physical spaces (i.e., accelerometers to measure sea level, roadway sensors that provide real-time traffic information), embedded in domestic architectural spaces (i.e., smart thermostats and security systems), in personal devices (i.e., fitness bands that measure heart rate and calories consumption), and in implanted medical devices (i.e, pacemakers that monitor heart rate and silk-silicon patches that monitor the level of glucoses in diabetic patients). As a consequence, the construction of hybrid spaces in the IoT is no longer bound to the direct relationship between geolocation and digital information. While hybrid spaces, framed by the field of mobile media, points to the impact of mobility on the representation of "static" geographic/physical space; hybrid spaces, framed by the dynamics of big data mining, do not necessarily reference a unified, pre-existent physical space. Hybrid spaces in the IoT are constructed as self-referent representations of datasets, they are parsed out, engineered, to tend to particular contexts and needs. This new construction of hybrid spaces is still tied to the physical world, as sensors transcode physical reality into computational data, but they are not necessarily grounded on geographic coordination. For example, the diagrams created by Frederic based on the data collected about his sleep (figure 14) are spatial representations of a hybrid space. These graphs map the physiological performance of Frederic's physical body. Conversely, the data visualizations inform Frederic's knowledge about his physiology and prompt him to introduce changes that might affect his physical body.

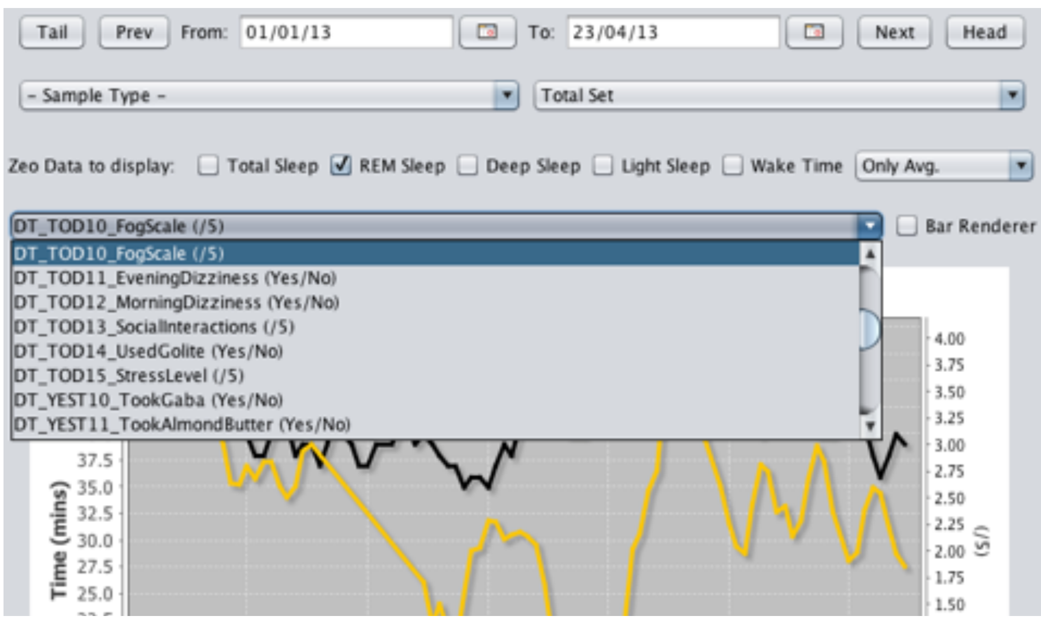

Figure 14: Possible data correlations for the variables monitored by Frederic to assess his sleep.

The production of hybrid spaces occurs through diverse topologies of data correlation, built in multiple scales—from the small scale of personal data gathered by one user like Frederic, articulated with the large scale of personal data of many users gathered by Google Analytics. A topological analysis is valid in this case because each mode of data collection constructs a form of spatial knowledge, let it be the internal space of the body of the physical space of a smart city. As I argue in the introduction of this dissertation, by considering the Internet of Things as built upon dynamic topologies of rhizomatic structures, I am acknowledging that these spatial forms of knowledge are open-ended and articulated. With this in mind, I suggest the following topologies of hybrid spaces (Table 1). The main goal of this analysis is to acknowledge how the logics of big data mining sustain the concept of hybrid spaces and the spatiality in the Internet of Things. Therefore, the main directive for the topologies of hybrid spaces is how data gathering, data analytics, and visualization are enacted by users and technologies, from active/intentional data collection to sentient big data mining. The following analysis describes topologies of hybrid spaces also taking in consideration the heterogeneity of networks, the multitude of devices, and the variety of protocols that are intrinsic constituents of the Internet of Things.

Even though each topology below is described according to how it responds to the mentioned criteria, these topologies are interrelated, and are not autonomous or self-sufficient. The distributive and co-constitutive interrelation between social forces, materials and technologies construct topologies that are only productive in relation to each other. They are not structured as a clear cut taxonomic hierarchy, in which one is a subset of the other, nor as resulting from a historical progression of technological development. As such, the first topology I describe is not created by more "primitive" technologies than the next ones. The use of pervasive computing and data mining strategies to create a hybrid spaces does not overwrite other forms of space-making and other epistemes of knowledge production. As Bolter and Grusin (1999) argue, the development of new media, and in consequence, new forms of knowledge construction, implicate in a remediation of previous media. There is no transcendence or complete rupture, "media are continually commenting on, reproducing, and replacing each other" (p. 55). As much as digitization is an undeniable global trend, digital infrastructure is not geographically uniform. Cultural, political, and economic differences also rearrange the forms of technology appropriation—which makes the configuration of the IoT networks specific to each location. The availability of infrastructure is diverse and the levels of access to the management of big data are asymmetric among those who collect and those whose data is collected.[69] In summary, these topologies are schematic instruments to assist in my interpretation of the epistemological shifts that occur in the appropriation of big data mining in the IoT.

TOPOLOGIES OF HYBRID SPACES

Heterogeneity of networks →

	TOPOLOGY 1: Data annotation	TOPOLOGY 2: Data doubles	TOPOLOGY 3: Predictive data models
Data collection and processing	Actionable	Actionable/Automated	Automated/Sentient
Pervasiveness	Mobile	Mobile/Embedded	Embedded/Invasive
Interface	Visual/Screen-based	Visual/Screen-based/Haptic	Biometrics/Sensors
Action	Tracing physical space	Data sensing/correlation	Predictive models of big data
Platform	External device (carried by the user)	Wearable device (attached to bodies of people and things)	Integral to bodies of people and things

Table 1. Topologies of hybrid spaces varying according to the embodiment of spatial practices, the materiality of infrastructure and the action-to-knowledge.

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[69] For a detailed discussion about big data divide, see Mark Andrejevic's *Big Data, Big Questions. The Big Data Divide.* Retrieved fromhttp://ijoc.org/index.php/ijoc/article/view/2161/1163

Topology 1: Hybrid spaces as data annotation

This first topology emerges from the intentional and actionable generation and collection of data by the user. In this topology, data collection only occurs when purposefully initiated or allowed by the user, such as self-reported data collection. This dynamics of data collection is present in the Wiki Mapas (2010) project in the Pavão-Pavãozinho slum in Rio de Janeiro, Brazil (Duarte and de Souza e Silva, 2014) created by the NGO "Rede Jovem." The project consists of collaborative mapping of streets, points of interests, services and resources in the slum using a mobile phone application and aerial images from Google Maps (figure 15). Favelas in Rio de Janeiro are the result of over one hundred years of informal occupation of land. Faced with the increasing living expenses in urban centers and the gentrification of neighborhoods in the early 20th century, lower income population were "forced" to settle on the hills that surrounded the noble areas of the capital (Gonçalves, 2013). Because favelas were not part of cities' original urban planning, these urban spaces are composed of makeshift shacks and lack basic services such as water, gas, and electricity. Along with the absence of basic infrastructure, there is also a lack of spatial and information mapping—even though the avenues that give access to favelas are formally named and appear on city maps, once you enter the favelas and go uphill you find yourself in a maze of curvy narrow streets and alleys. Even though this organic architecture is well known by the residents and are informally named by them, they are not featured in official city maps as actual addresses. By accessing the Wiki Mapas app on the phone or on the Wiki Mapas online platform, the favela residents are invited to include location markers for streets, business and services, and events.

Figure 15: Part of the favela map produced collectively by residents of the favela Pavão-Pavãozinho.

Through the collective construction of representation of the favela, the use of the technology also reinforces a sense of community. The main relevance of projects like WikiMapas is the sustainability of collaborative practices embedded in hybrid spaces, as mobile technologies are appropriated to shape the social geography of locations. Location-based services (LBS) emphasize geo-location as they remediate how users relate to places. WikiMapas, for example, brings into visibility geographic locations that were formerly “invisible,” that is, locations that have never been mapped. Through location-aware information, these locations can be visualized via mobile devices and accessed by users who were not familiar with the geography of the slum. The lived practices of LBS include not only the data annotation and data attachment to locations, but also the sharing and creation of social networks around the use of these services.

In this topology, smartphones and other similar screen-based devices, are the most common interfaces for data collection and processing. By mapping geolocated spaces (i.e., WikiMapas in favelas), checking-in on a restaurant in Foursquare, users are routing and tracing their spatial practices onto hybrid spaces, which, as de Souza e Silva (2006) defines, blur the borders between physical and digital environments.

In my observation of the discussions in the Quantified Self forum, users shared reports on how to gather data about their bodies:

Tafkas: In June I charted my last five years of weight tracking:

I have been tracking my weight since the summer of 2008. First manually and later using the Withings scale. The R code to generate the chart can be found at my blog.[70]

[70] https://forum.quantifiedself.com/thread-five-years-of-weight-tracking/

While some users adopted smart appliances and apps to actively collected data about their physiologies (i.e., weight tracking), others created metrics to log almost every aspect of their lives:

> imadp: Hi guys, I'm the owner of http://www.tracktacular.com, a life logging site designed to track your life in one place. I built it because I felt very disorganized tracking different parts of my life in different places, and instead wanted one site to pull everything together. The site focuses on more macro than micro tracking—things like tasks, goals, dreams, cholesterol, books, restaurants etc. It's right up the alley for quantified selfers (...)
>
> FeniV: Wow. The amount of features on that website is quite impressive. You have a section for EVERYTHING! (...)
>
> imapd: Why thank you! It didn't always have this many features of course, I started out with only the Task Tracker and added more and more over the years. I'd like to add either a Travel or Ailment (sickness, surgeries) tracker next.[71]

This topology is marked by the use of screen-based devices for annotation of data. Smartphones and apps are frequently used for data logging and data visualization because of their portability and convenience.

Topology 2: Hybrid spaces as data doubles

When users and app developers started using sensors that are present in mobile devices to gather data (i.e., gps and accelerometers), we witnessed a transition to automated forms of data collection. This marks the emergence of a second topology. Smartphone accelerometers are used by apps to count steps during physical activity, as

[71] https://forum.quantifiedself.com/thread-tracktacular-tracking-multiple-things-in-one-place?

the variation of the values of the axis X, Y and Z—a geometrical representation of tridimensional space setup in a sensor inside the phone—is transcoded into walking movement of the body that carries the phone. At the same time the movement of this body is traced by the GPS in geographic space. On the screen of the smartphone, the user can visualize the route, average speed and calories burned (estimated by a preset correlation of intensity and duration of physical exercise). In this case, the technological arrangements of GPS, cloud computing, smartphone, and body of the user are setup so that the agency in the creation of her spatial performance is distributed in this arrangement. In this topology, automated data collection and analytics marks how the production of hybrid spaces does not always follow parameters controlled by the user. Other wearable devices with haptic interfaces, such as fitness bands and heart rate sensors, are built to collect data continuously as long as they are being worn by the user. The data output is parsed out by the app software and gives the user a graphic visualization of the results, but commonly does not provide access to native data. A discussion in the Quantified Self forum between Asher and John about how to parse out personal data exemplifies this situation:

> Asher: John, I like all the sensors that BodyMedia had, but I like having access to the data too. I am not interested in a device that uploads my data to a silo where it is irretrievable, or retrievable only in summary form. A real time app would be good, but better would be having access to the real time data directly. The issue for me is that these types of devices do certain things quite well but do not do everything, and so when using multiple devices I want to have all my data in one place, as much of the value comes from the connections between the data sets.

The same goes for real time data; if I need a different app to see data from each device, it becomes far less useful.

John: One point of information about simply collecting the raw data—it is hard to interpret. I have a subscription so I can leverage their algorithms to tell me what is happening right now. Can you more clearly define your desire for a "real time" data? Are you looking for updates every 1 minute, 5 minute or streaming?

Asher: For real-time data, it depends on what type of data it is of course. For things like GSR and temperature I think I'd like to be able to get pretty short intervals between samples, so essentially streaming. In practice this might be once a second or something like that, but I definitely wan't intervals that allow you to monitor change in real time rather than 1 or 5 minute updates. I haven't yet looked closely at the research to see what kind of temporal resolution is 'enough', but I'm assuming things like GSR can change pretty frequently.[72]

This discussion demonstrates an intriguing paradox: While personal data mining allows for the creation of a great volume of data, the user cannot make sense of the data in its native format. The data analysis and visualization must be outsourced to an algorithm to output graphics that brings forth data correlations that otherwise could not be assessed. This is a paradox that is present in many other discussions in the Quantified Self forum and marks one main challenge of automated data collection: how to make sense of the ever-increasing size of databases. Another main challenge is also present in this discussion: the desire to gather as much data as possible, without any interruption. As discussed earlier in this chapter, the use of sensors to constantly gather personal data

[72] https://forum.quantifiedself.com/thread-bodymedia-alternatives

follows the logics of big data. Wearable sensors are also marketed to reinforce the ideal of building an exhaustive representation of physical reality—in the model of Jorge Luís Borges short story, “On the Exactitude of Science,” where the perfect representation is a map as large as the territory.

In the Quantified Self forum, other users have also appropriated sensors to explore how physiology interacts with other forms of wearable technologies. McGee reports his experience using Hexoskin, a shirt (or, as the developers define it, a body metric system) woven with several sensors that measure heart and breathing rate, number of steps, speed of pace and calorie consumption.

> McGee: The heart rate sensor on my shirt is not picking up much a signal. The breathing sensor is ok. There are 3 in total. I’m hoping I’m able to re-position the sensor into the correct spot as it could have slip out of place when they were sewing it together. It is channeled inside of the shirt. I think a shirt is the way to go instead of a harness. I’m wearing a Lumoback back posture sensor right now. It always rises up or out of the position it should be in.[73]

Hexoskin promises to deliver a “longer, healthier and happier life” if you listen to your body (translated by Hexoskin algorithm’s, that is). This tagline demonstrates how much of the parameters for decision making are outsourced to intelligent algorithms and how the ideal of a perfect human being is transformed into an ideal of always-perfecting quantified method of subjectification.[74]

The data collection and processing in this topology occurs through the automated collection of senseable data in the physical world. The use of wearable sensors by users

[73] https://forum.quantifiedself.com/thread-hexoskin-is-shipping-to-backers?highlight=hexoskin
[74] I recover this discussion on the next chapter when I discuss modes of self-making as self-governance.

of the Quantified Self forum, for example, aims to create an accurate representation of their physiology. Through data correlation and intelligent algorithms, patterns can be identified in the dataset and inform users about the interrelationships among variables. Hybrid spaces, in this topology, are constructed as users build “data doubles” of their own bodies. They are constituted in the interplay between the users’ physical bodies, the increasing bulk of data gathered by sensors and the data visualizations created by algorithms.

I must clarify, though, that my emphasis on personal data is due to one of the goals of this dissertation which is to address how pervasive technologies devise practices of self-making. Also because the object of my analysis in this chapter is the Quantified Self Movement, which is centered on personal data. However, the construction of hybrid spaces through automated mapping is not constricted to the scale of the individual body and can be extended to the larger scales of populations. Multiple sources of personal data—physiological information, user geo-location, traffic flux, etc.—are automatically gathered, correlated with other big data sets and outsourced to build data visualizations. The project LIVE Singapore, developed by Carlo Ratti at the MIT Senseable Media Lab, provides an online platform with real-time data that inform how people use the space of the city (Ratti, Claudel, Kloeckl, 2014). The purpose of the project is to inform city developers and citizens, offering new insights for urban planning and city services. The data sources vary: traffic flow, rainfall, temperature, electricity consumption, cellphone network usage and airline cargo flow are some of the variables collected in this project.

Figure 16 shows one of many data visualizations rendered on the LIVE Singapore platform. This visualization represents traffic flow and estimated travel time. It is built based on geolocation information and travel time data from 16,000 taxis. The visualization is an interactive, dynamic image that is updated in real-time, synced with the data collection. Depending on the condition of traffic, the map distorts Singapore's physical contours to reflect the time it takes to get from one point to another. For example, if traffic is slow and travel time is long form A to B, the island grows larger between the locations; while with fast traffic and shorter travel time, the represented distance on the map diminishes and shrinks the size of the island.

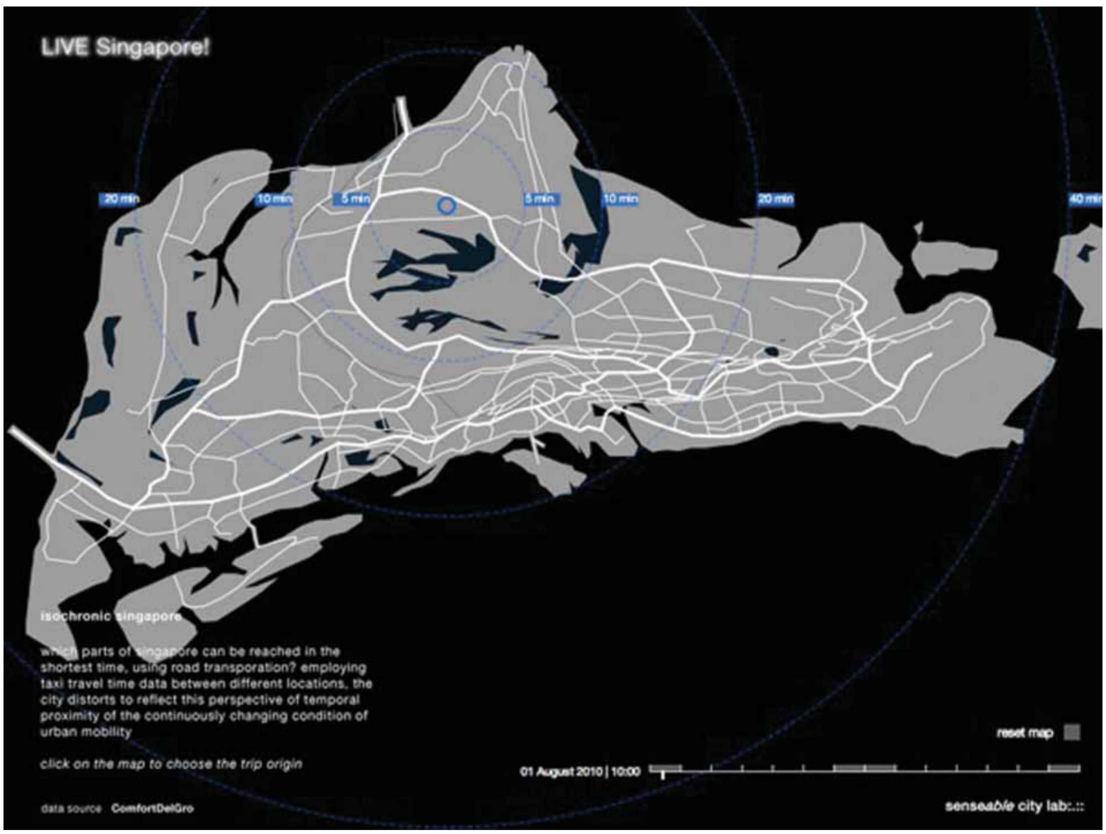

Figure 16: One of the data visualizations created by the LIVE Singapore! project. The size of the territory of Singapore changes based on travel time data sourced from taxi drivers.

LIVE Singapore! does not aim to be a single application to simply inform the most efficient way to get from point A to point B, as a typical navigator would. The data visualizations are closer to an "ecosystem and a toolbox for real-time data that describe urban dynamics."[75] Based on the variables gathered by the platform, other users can establish different correlations and generate meaningful interpretations of how to occupy the physical space of Singapore.

In the example of LIVE Singapore!, hybrid spaces are shared between users accessing the map and users driving in the city—who, by inhabiting the physical space of the city, unintentionally contribute to data generation and affect the visual representation of the map. Based on what the data visualization informs regarding travel time and traffic status, for example, people in Singapore make decisions about which route to take, which locations to avoid. They use the data visualization as a tool to plan how they will later experience physical space and engage into a real-time feedback loop between people moving in the city and the gathered data through the online platform. The creation of hybrid spaces to assist in decision-making marks the transition to the third topology. In the next topology, automated data collection for specific purposes, such as monitoring of heart rate, is expanded to 24/7 sentient data collection of all possible sources of data. Even when the purpose of collection is not clear, data correlation and analysis pushes the construction of hybrid spaces towards predictive models.

Topology 3: Hybrid spaces as predictive data models

As sensor networks and the dynamics of big data are largely distributed in physical spaces and bodies, big data mining is increasingly more sentient and data analytics gain more sophisticated tools for data correlation. In this topology, a greater variety of sensors and heterogeneity of networks produces "mass dataveillance" (Clarke,

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[75] See other visualizations at http://senseable.mit.edu/livesingapore/visualizations.html

2003), through aggregation of data from different sources: cookies in internet browsers, implantable RFID tags in documents, implantable chips to track individuals' movement and exact location, medical data to map the spread of infectious disease among many others. All digital traces are gathered not only to describe real-time data activity in physical space (as described in the previous topology) but to creative predictive models based on identifiable communication patterns in the gathered data.

Andrejevic's (2014) and Packer's (2013) discussions about drone surveillance are good examples of how big data mining generates preemptive action by governments and the military. Packer (2013) explains how drones operate in war:

> Drones are the experimental forefront of both observation and response. They not only collect the data but are increasingly being given the task of processing the data. Finally, the chain of command that led from deciding who was the enemy (the political decision), to locating the enemy (the observational process), to executing the enemy (the soldiering process) is becoming a single digitally determined procedure. It is not simply that drones can locate real pre-existent enemies more accurately; rather they can collect and process the necessary data to determine algorithmically the threat potential of any giver situation/subject and act accordingly. (p.299)

In this topology, big data mining and data analytics are pushed to the limit of representation of current physical reality. The hybrid spaces that are enacted through data collected by drones do not aim to only depict the present reality. Based on the accumulated data and identified trends, hybrid spaces are built to represent future plausible realities and to inform decision-making that will lead us to the reality we want to create. Another example of application of big data mapping for predictive analysis is gene mapping. The first gene sequence was mapped in 2003. Twelve years later, about three billion pairs have been identified (Mayer-Schonberger and Kenneth Cukier, 2013). The correlation of genome data has allowed for the association of syndromes and illness to specific genes and to understand how genes interrelate to produce certain physical traits. Based on family history and the analysis of personal genome, for example, it is possible to calculate probability of manifesting genetically inherited illnesses, such as cancer. Predictive analytics play a major role in this topology, as data correlation can be condensed into statistics and inform, for example, a decision to go under preventive medical treatment. Even though this topology is built upon the accumulation of historical big data, from the past and the present; it is future oriented. Therefore, hybrid spaces in this topology are built as algorithmic models of physical reality.

Also in urban spaces, the use of big data mining techniques shifts the construction of hybrid spaces. New models of smart-cities are setup as test-beds, where the mining of present data about the current use of physical space of the city determines the reorganization of the urban space in the near future. Orit Halpern (2013) describes the implementation of Songdo, a smart city model in South Korea where every human and non-human movement can be traced, processed, and tagged to continuously promote greater work efficiency and productivity. Every material surface (i.e., a wall, a light pole) acts as a sentient sensor connected to a central processing center capable of transforming the city into an always improving, smarter and better physical environment. Songdo's smart infrastructure "wires every square inch of the city with synapses" and is supported by chips and sensors that talk to each other. Halpern (2013) describes Songdo's model even further:

> Cisco's strategic planners envision a totalizing sensory environment in which human actions and reactions, from eye movements to body movements, can be traced, tracked, and responded to in the name of consumer satisfaction and work efficiency. Every wall, room, and space is a potential conduit to a meeting, a separate building, a remote lab, or a distant hospital. The developers thus envision an interface-filled life propelled and organized by a new currency of human attention at its very nervous, or even molecular, level (p. 279-280).

Smart city models, such as Songdo, are built with a digital infrastructure that is capable of quick responses to computational algorithms. The probabilities compressed by the data analytics apparatus identify trends about the social use of the space of the city that govern the future of the current provisional model. songdo is always in beta version; it is an experimental hybrid space undergoing constant transformation. As Halpern (2013) defines, it is "an engine, not an image" (p. 290); that is it an algorithmic-driven physical space and can be continuously enhanced. Just as a city can be transformed, our physiologies can be algorithmically modified as sensors are embedded into our bodies.

Anna Munster (2006), in *Materializing New Media: Embodiment in Information Aesthetics,* foregrounds my argument of topologies of the Internet of Things as articulated digital folds, when she asks "What if we were to produce instead a different genealogy for digital engagements with the machine, one that gave us the room to take body, sensation, movement and conditions such as place and duration into account?" (Munster, 2006, p. 3). Munster (2006) argues that the idea of subjects that are weaved in as modes of territorialization and de-territorialization (following the analogy developed by Deleuze, in *The Fold*, about baroque folds) approximates to the fragmented characteristics of digital media environments, and contributes to a post modernist and feminist reconceptualization of the body. The baroque folds and the new media interrelate as an "enveloped and unfolding set of relations organizing the world" (Munster, 2006, p. 38).

The advances in gene mapping, implantables, silk silicon electronics, and bio-nanotechnologies data sensing also reaches a nano scale and turns the biological body into a metadata platform of networked connectivity. Brian Litt, AssociateProfessor of Neurology and Bioengineering at the University of Pennsylvania and Dr. John Rogers at the University of Illinois, Urbana-Champaign, are developing biocompatible and flexible microelectronics that can function as a platform for biosensors and networked computing.[76] The group has created silk-silicon meshes that function as arrays of conformable electrodes that interface with the biology (figure 17).

Possible applications are in deep-brain stimulation to control Parkinson's symptoms and around peripheral nerves to assist in prostheses' control.[77] The same silk silicon technology can be added to micro-organic LEDs to act as photonic tattoos that show blood-sugar readings and help monitoring diabetes (O'Sullivan et all, 2010).

The development of these nanotechnologies is concentrated in Bioengineering, Materials Engineering, and Computer Science. Most applications are in the medical and

[76] http://littlab.seas.upenn.edu/. Retrieved in October 2013.
[77] http://www.technologyreview.com/news/416104/implantable-silicon-silk-electronics. Retrieved in October 2013.

military fields. A major player in this scenario is the Defense Advanced Research Projects Agency (DARPA), part of the U.S. military and Department of Defense.

Figure 17: Clear silk film embedded with six silicon transistors as it is implanted in a laboratory mouse. Retrieved from http://www.technologyreview.com/news/416104/implantable-silicon-silk-electronics/

The Biological Technologies Office[78] under this agency has a broad portfolio of projects that range from diagnostic applications of nanotechnologies that allow for the constant monitoring of the physiology of soldiers to therapeutic treatment of prosthetics, post-traumatic disorder, and other brain injuries. In a domestic scale, Quantified Self adopters

[78] http://www.darpa.mil/Our_Work/BTO/Programs/. Retrieved in November 2014.

outsource gene mapping and lab work in independent laboratories to generate personal data and produce autonomous correlations.

> Jonah Larkin: Does anyone have a favorite place to get saliva hormone tests? I have used http://www.personalabs.com to get my blood tests done. The prices seem pretty good but the format in which they output their test orders was very confusing to the lab and they ended up missing a couple of tests. I had to make another trip to the lab to get the tests that they missed.[79]

The opacity of data collection and the levels access to this data is a controversial issue that is also present in the forum discussions. By collecting personal data themselves, running lab work independently of medical proxy and processing data results through custom built algorithms, users try to regain data ownership.

> Anne: We have been dreaming about how cool it would be to enable people to collect heart rate variation/cardiac coherent data as they go about their daily lives, and then later explore and reflect on the results along with other time-synchronized contextual data to help make sense of what was going on when. It's one of the types of data we think would be high leverage for people using Body Track to understand environment/wellness interactions.[80]

The posts above demonstrate great levels of investment on aspects of self-tracking: ownership of personal data and correlation for predictive data. The data collected by the heart rate sensor described by Anne allows the mapping of numeric

[79] https://forum.quantifiedself.com/thread-what-are-the-most-important-blood-tests-to-get?highlight=testing
[80] Available at https://forum.quantifiedself.com/thread-emwave2-heart-rate-variability-monitor

values produced by the sensor onto physiological behavior.[81] Anne's post is commented by another user:

> JxA: My ultimate goal is to have a feedback on my stress levels while performing activities on the computer. I would like to know when my anxiety starts rising and then I would determine a level, where I have to intervene by focusing on my logic and injecting logic. Best case scenario would be that I would have several cues that I am approaching this point such as changes in HRV, breathing rate and body temperature.[82]

As JxA's and Anne's posts demonstrate, the users on the Quantified Self forum are constantly searching for more accurate and complex sensors to build a totalizing territory, a complete representation of their physiological bodies. Through the attempt of regaining data ownership, users also try to gain leverage over how well their bodies fit in the predictive hybrid spaces they are part of. The desire for this totalizing self-representation feeds into the frenzy of technology fascination and a narcissistic desire for immediate positive reaffirmation of being a healthy, smart, and productive human being.[83]

As the previous examples demonstrate, the development of sensing technologies and the employment of big data mining techniques mark a move for a new form of spatial epistemology that is not only concerned with the factual current mapping of physical spaces. In the examples of the mapped spaces of smart cities, human physiology and drone surveillance, the representational effort is geared towards predictive spatial models

[81] I discuss this issue of mythification of raw data on chapter 5.
[82] https://forum.quantifiedself.com/thread-emwave2-heart-rate-variability-monitor
[83] In the next chapter, I discuss further how the appropriation of sensor technologies produces techniques of self-making.

based on data correlation. While in the previous topologies, hybrid spaces are bound to physical reality as a signifier is bound to its symbolic representation, in this topology hybrid spaces are self-referent, constructed as data-territories that emerge from algorithmic performance.

Conclusion

This chapter discussed how big data mining techniques can be put into practice to produce topologies of hybrid spaces. These topologies vary as data mining gains greater levels of automation and as sensors and networks that constitute the IoT become more heterogeneous. The first topology is characterized by self-reported data collection, meaning that the user must initiate the data gathering process. As exemplified by the WikiMapas initiative, data annotation is dependent on the user's action. To make the data collection process feasible, users rely on the portability screen-based devices. The convenience of location-based services and mobile media devices makes them prominent platforms for hybrid spaces in this category.

The second topology is marked by the increasing pervasiveness of automated data collection and processing techniques. The use of fitness bands that continuously measure physiological information, with little input from the user, is an example of a data collection method. While the first topology depended mostly on screen-based devices, in this topology haptic interfaces are also present. Sensors worn by users or attached to things transcode physical reality to digital data, which will later be synced with an application that processes the data into comprehensible information. Hybrid spaces are constructed through the interplay between physical bodies/spaces and the data visualization created through the algorithmic correlation.

Finally, the third topology pushes data mining and data analytics to the limit of self-reference. Even though data is mined from specific physical spaces at a specific time, more complex correlations are established with accumulated data to observe historical trends. Data processing in this topology aims to build predictive models based on the analysis of past and current patterns of communication. The main goal in this topology is to construct hybrid spaces that are always sentient to physical realities and therefore are constantly improving upon their predictive models, and informing better decision-making. Sensors that gather data are integral components of the body being monitored; data mining is, by default, the *modus operandi* that shapes the constitution of a hybrid space. In all topologies, data mining occurs at multi-scalar levels (from smart cities to the molecular level of physiology) and materializes an algorithmic form of knowledge of our biologies through data correlation of massive databases.

In the next chapter, I address how the transformation of the body into a networked site of computation creates different practices of subjectification/self-making. To do that, I analyze current appropriations of wearable technologies and sensor by followers of the Quantified Self Movement, as a strategy to reterritorialize the self through numeric data. I also analyze “Truth or Dare” as a critical experiment that demonstrates how the naturalization of digital data as objective measure for Truth translates to parameters of self-knowledge.

CHAPTER FOUR

Self-making

"Through data correlation we will find and learn everything we ever wanted to know". MichaleDKester[84]

While I followed the discussion threads on the Quantified Self forum, I gathered a diverse collection of self-tracking projects. Users are tracking their physiology, for example, through body weight, heart rate variation, genomics mapping and hormone levels; their daily activities through active logging of tasks and geo-location mapping; their mental health, through mood tracking and cognitive tests; to name a few. Users frequently refer to scientific scholarship to establish desired baseline values and use off-the-shelf gadgets or open hardware/software they built themselves to collect and assess personal data. And by doing so, users build a sense of self based on the collection and correlation of this data. After observing the Quantified Self movement, I decided to take on self-tracking myself and experience the routines and methods I had been witnessing first-hand. I chose to use a Misfit Shine[85] (figure 18) wristband sensor to keep track of physical activity and quality of sleep. The Misfit Shine is very similar to a watch, in which the face of the watch is actually a case that houses an accelerometer sensor, a circuit board and battery, attached to a wristband. It works very similarly to a pedometer, with the exception that the accelerometer can measure movement through three-dimensional axis and therefore assess intensity and direction of movement more

[84] https://forum.quantifiedself.com/user-michaeldkester
[85] http://misfit.com/products/shine

accurately. The sensor communicates with an app via bluetooth for setup, data collection and visualization. Through the app, the user sets up types of physical activities (swimming, cycling or walking/running) and a daily goal (i.e., if walking/running, the goal is defined by number of steps). The face of the watch has micro LEDs distributed in place of numbers. By tapping the surface of the watch twice, one of the LEDs first lights up to show the correspondent hour and another LED blinks to show the (approximate) minutes[86]. Next, the Misfit Shine lets you know how far you are in terms of your daily activity goal. If you are halfway through your daily goal, for example, the first five LEDs in clockwise sequence light up to show that you have accomplished 50% of your exercise quota. Because I wanted to account for all physical activity and build enough historical data to recognize patterns, I wore the Misfit Shine all the time. Every morning, when I synced the sensor with the app I was provided with the number of steps, calories burned and a graph about my sleep that showed sleep and awake times and number of hours of actual sleep (figure 18).

Figure 18: The Misfit Shine is available for sale at a starting price of $55. An entry version of the device, called Misfit Flash, with similar sensor but cheaper material is available for $29.

[86] Since the face of Misfit Shine is composed by 12 LEDs, it can only display minutes in intervals of 5 minutes.

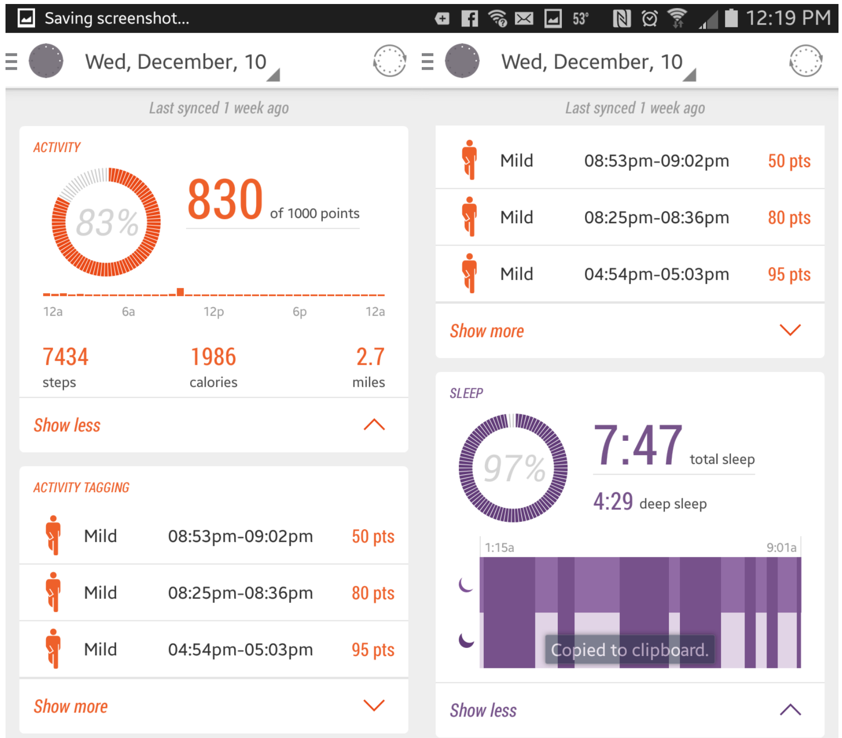

Figure 19: Print screens of the Misfit Shine app showing graphs of physical activity and sleep.

I set my daily goal for 10,000 steps and 8 hours of sleep. Throughout the day I checked my progress and as I could, I adjusted my day to get myself closer to achieving my goal. As I started syncing the data with the app I couldn't help but to feel that there was a mismatch between what the graphs showed and my personal perception of my physical activity. The black box structure of the app did not disclose the parameters for the classification of activities as mild/intense, nor for how calorie consumption is calculated. The sleep graph showed me restless nights of sleep when I felt that I had had a soothing night. The empowerment I felt as I monitored my progress towards the goal I had set up was quickly undermined when I synced the sensor with the app and could not reconcile my subjective experience with the visual representation of the data. I saw myself in a similar place as the users of the Quantified Self forum: doubting the capacity of the hardware to accurately sense my physical performance and wishing for ways to access my data directly, unfiltered by the automated, app-generated graphs.

Still, the Misfit Shine functioned for me as a self-accountability tool. I had defined an ideal of physical performance and every time I tapped on the face of the sensor, the LEDs lit up to inform how far or close I was to achieving my goal. Five LEDs lit in sequence tell me that I am halfway through my 10,000 steps quota. I felt prompted to compute more steps, double-tap again and see if my effort was acknowledged by the Misfit Shine. The LEDs gave me an objective measure and provided evidence that I had in fact made progress towards a better physical shape. Also, worked as a form of symbolic compensation of my progress and reassurance that my physical movements were being captured and tracked accordingly. The importance/impact of this symbolic retribution was made clear in the first time I reached the 10,000 steps goal. All the LEDs lit up in sequence creating a stop motion animated sequence of a running LED on the face of the watch. The celebratory lights produced a celebratory affect and a motivational effect that drove me to continue tracking my physical activity. Even though my critical reasoning made me aware of the strategies of knowledge construction through self-tracking I still felt part of a *Pavlovesque* experiment and conditioned to make all LEDs light up again.

During the time I engaged with self-tracking, the use of self-tracking tools forged my sense of self and the perception of my body. For dedicated self-trackers, such as the users of the Quantified Self forum, the data collected and aggregated is naturalized as “truth” about their bodies. Similarly, some of the interactions I observed during the Truth or Dare installation showed how the construction of “truth” is taken at data-face value.

Alternatively, the audience of the ToD installation questioned the intention of the piece by engaging with it ironically and posting absurd tweets, and critically by questioning the premise of an automated objective measure for moral judgment. Some users of the Quantified Self forum also denounce an obsession with quantification and the risks of conflating correlated data with a more accurate depiction of reality.

In the previous chapter I addressed my first research question[87] and demonstrated how the materiality of digital data and practices of data mining produce forms of knowledge in scalable dimensions: from the micro dimension of the self to the macro dimension of social politics. The pervasiveness of digital media across all dimensions of life has shaped processes of knowledge-making accordingly to the epistemic actions of digital data. As overlapping topologies, data mining renders multi-scalar hybrid spaces and enacts an algorithmic form of knowledge of our biologies through data correlation. The transcoding of the analog world into binary information creates non-semantic metadata which levels the playfield between human and machine actions and allows for the collection and correlation of data. As subjects construct new objects of knowledge based on new strategies to generate, aggregate, and analyze data, this new knowable reality also speaks about the subjects that are immersed in it.

In this chapter I reaffirm the pervasiveness of a digital episteme (Maddalena, 2014) to address the second of my three research questions and answer how pervasive computing technologies devise practices of self-making. To do so I provide illustrations of different practices of technological self-making in the Internet of Things that range from self-tracking experiments reported in the Quantified Self forum in which the body

[87] How are embodied spaces produced through the appropriation of pervasive computing technologies?

and the mind are the sites of investigation, to the construction of computational parameters for truth in the ToD installation. The interactions with the Truth or Dare installation and the discussions in the Quantified Self forum reveal a wide range of symbolic negotiations that shape the construction of mediated subjectivities. I discuss these practices of self-making as a form of self governance (Foucault, 1997, 2003) enacted through the material organization of digital technologies. The discussion about self-making in this chapter extrapolates the Cartesian separation between subject and object of knowledge by examining subjectification as a construction of self knowledge through pervasive computing technologies. By doing so, I reinforce the relational dynamics of human and non-human actants as collective sociotechnical assemblages of enunciation in which the self is simultaneously a product and the producer of the assemblage she is part of—"there is no difference between what a book talks about and how it is made" (Deleuze and Guattari, 1987, p. 4). As assemblages are relational by definition, the self is never found in a static position. Thus, the self is constantly being reinvented as a field of relations laboring its own transformations.

Before describing the self-making practices I observed during the ToD installation and in the Quantified Self forum, I position this discussion in the wider context in which digital data is taken as an objective measure for reality. This chapter develops from the discussion in the previous chapters when I address the role of sensor technologies in transcoding physical reality into digital values. It also contextualizes how the materiality of the digital and the logic of data mining shapes forms of spatial knowledge from the molecular scale of the body to the macro scale of social politics. To conclude this contextualization and to demonstrate how the making of the self is grounded on the digital episteme (Maddalena, 2014), I approach digital metering from a socio-historical perspective and present the motivations that beget objective measuring practices. To do so I briefly overview the roots of digital metering as emerging from a wave of rationalization of scientific discourse (Kuhn, 1961) and therefore of the forms of knowledge that define what is a subject (Foucault, 1980, 1984a). I also articulate the development of technologies of control post-industrial revolution (Beniger, 1986) with the modern desire to control over how the self performs in space and time (Wise, 1997).

Quantification: the wider context

In the heart of all self-tracking practices lies the desire to measure, keep score, evaluate past, and enhance future performances. The self-tracking practices that characterize the Quantified Self movement, as the measuring of truth in the Truth or Dare installation, feed into a circuit of reproduction of a digital episteme (Maddalena, 2014) founded upon how discrete numeric information can be aggregated and correlated. Quantification and digital technologies share a symbiotic relationship because the mathematical setup of digital media is what makes it manipulable, compressible and interchangeable. Digital media objects can be described formally through numeric representation and can be reorganized through algorithmic manipulation (Manovich, 2001).

However, the reduction of symbolic information to discrete units, as Maddalena (2014) argues, is not inaugurated by digital technologies. It follows an operation of discretization of more nebulous and continuous forms of knowledge to isolable, independently determined, malleable units of information; for example, the Morse code and the telegraph. In her dissertation, Maddalena (2014) introduces LEGO blocks and gene mapping as illustrations of how the employment of epistemic digital values is extended beyond typical digital computing technologies. In both cases, manipulative models are created based on differential articulation, replication and scalability of the same standardized basic unit: either a plastic or a protein brick. In this sense, the core of the digital episteme is defined through "the atomistic and non-semantic attributes of digital symbolic objects" (Maddalena, 2014, p.59). For this reason, the digital episteme, as a way to know the world translated into discrete, quantified, correlatable and scalable non-semantic units, is prevalent even if the process of knowledge construction is not mediated by computing technologies or digital applications.

The rise of quantified data is problematized by Thomas Kuhn (1961) in the article "The function of measurement in Modern Physical Science", in which he addresses some concerns in the centrality of quantification in scientific discourse from 1800 onwards. He points out that quantified measurement in empirical experiments feeds into systems of belief that sustain laws and theories in fields of science instead of challenging the rhetoric of their constitution. The issue that Kuhn (1961) calls attention to is the mythical function and aura of efficacy that objective measurement takes on, specially in the teaching of science in textbooks. Textbooks are the point of entrance to the scientific method and they perpetuate a myth about the exactitude of measurement of physical reality that is misleading. To illustrate his argument, Kuhn (1961) compares the presentation of the textbook to a programmatic machine that obeys "law like" statements and outputs numbers without changing the programming conditions (p.163). The function of quantified result is to verify the validity of theory, which in result, either confirms or challenges it. When measurements are collected and verify a theoretical hypothesis, "(…)

they yield mere numbers and their very neutrality makes them particularly sterile as a source of remedial suggestions" (Kuhn, 1961, p.180). When the opposite happens and the measurements challenge the initial hypothesis "(…) numbers register the departure from theory with an authority and finesse that no qualitative technique can duplicate, and that departure is often to start a search" (Kuhn, 1961, p.180). In this case, the objective measures are generalized as a new theory. In either case, the efficacy of the scientific finding is attributed to the validation of numeric measurement. The textbook functions as a semi mechanical schema in which the results of measurement are understood as neutral and precise (Kuhn, 1961, p.165). Kuhn's (1961) critique is that in textbooks, the greater system of knowledge per se is not questioned.

The development of instruments is tied to the development of a quantified system of knowledge because instruments allow for accurate measurement. For example, the explanation about natural phenomena such as magnetism, energy and light were theoretically advanced but lacked instrumental evidence of their mechanisms. Newton's optics advanced when the mathematical proofs of refraction of light bridged the gap between the observable reality and theory. The scientific practice of quantifying observations turns the potential theory into actual discovery. Kuhn (1961) refers to this "mopping-up" operation as the normalization of measure as a scientific fact. In the interaction between building more accurate instruments to measure physical reality and the presumed accuracy of numeric representation output by these instruments, a scientific discourse sustained by quantitative methods gained momentum in the physical sciences and beyond.

The organization of forms of knowledge into discrete and measurable units is an effect of a process of modernization which is marked by the increasing rationalization and control of the subject through institutional and economic requirements. The process of normalization of science, as described by Michel Foucault's analysis of madness and the birth of modern medicine (Foucault, 1965, 1970, 1973) demonstrate how a subject of knowledge is tied to a historical analysis of social divisions. Self-tracking through the quantification of personal data is an effect of a modern process that in the nineteenth century rationalized the subject as knowable and calculable through with the development of statistics (Foucault, 1978). Foucault explains that the rise of the industrial revolution coincides with new methods to administer labor, and in consequence, to administer the efficiency of workers' bodies. Modernization consists in the production of manageable subjects through a

> certain policy of the body, a certain way of rendering a group of men docile and useful. This policy required the involvement of definite relations of power; it called for a technique of overlapping subjectification and objectification; it brought with it new procedures of individualization (Foucault, 1978, p. 225).

Through numbers, the scientific premises that manage the economic efficiency of the workplace (completing tasks at maximum speed and minimum cost of materials and labor), measure life itself as it creates statistical parameters for how productive bodies must perform. Therefore, the use of quantifiable measures produces an overlapping between instances of subjectification and objectification, and render a way of making the self that is tied into economic, scientific and institutional forms of knowledge.

These new procedures of individualization—which I refer here as practices of self-making—depend upon the accumulation of knowledge about the subject as an object of scientific discourse. The conceptual "bodies of knowledge" (science) are intimately tied to the constitution of material individual bodies (biological subject), for example as a speaking subject (Linguistics), as a productive subject (Economics) or a living subject (Biology). The fixing of statistical and quantitative norms of behavior is crucial for these scientific forms of knowledge to function as disciplinary techniques of subjectification. The assessment of "normalcy" in comparison to madness, in psychology; or the assessment of a productive body in the economy of labor, for example; draws from measurable forms of knowledge that enable the management of the population[88] (Foucault, 1965, 1970, 1978). Subjectification is operated through a dialectical dynamics of forces of enunciation, and the creation of the subject in this archaeological analysis has a negative bias, which means that the individual is made into, conditioned as a subject. Foucault's analysis of madness demonstrates how the organization of <u>scientific bodies of knowledge</u> is dependent upon the relations of how <u>biological individual bodies</u> are constructed through discourse. The development of physiology as a field of scientific knowledge in the nineteenth century (Crary, 1992) turned the body into a foreign territory to be explored, mapped and mastered. The use of instruments to measure pulse, to listen to the heart rate, to observe the response of the eyes, added with procedures to collect and compare historical data of patients also turned the body in to a site of both power and

[88] Jonathan Crary, in "Techniques of the Observer: on vision and modernity in the nineteenth century" reminds us that during the first half of the 19^{th} century measurement takes a primary role in physical sciences. Quantitative research also gains prominence in social sciences. In 1832 Charles Babbage, inventor if the digital computer, published a pamphlet urging for the publication of tables of all known constant numbers in the science and in the arts.

truth. The empirical knowledge gathered by the observation of the anatomy and physiology of the body through these early instruments turned physiology, as a science of life, into a new method of exercise of power.

In the beginning of the previous chapter I described how Frederic keeps track of his heart rate variation, sleep activity, brain wave frequency, body weight, blood pressure, calorie intake, among others. Frederic uses devices and sensors to monitor a total of forty different variables which are correlated to reveal dependencies that he did not foresee (i.e., a relationship between the consumption of a group of food and sleep activity). Through data correlation Frederic creates knowledge about the performance of his body and is prompted to make decisions to alter his behaviors in order to get closer to standard health values (i.e., the targeted values for body mass index). He can then observe how the change of his habits produces different data values and live in continuous self-experimentation forged through/by the continuous creation of knowledge about his body. The point that Kuhn (1961) calls attention to in the discussion about the role of measurement in physical sciences and that Foucault demonstrates through this empirical analysis is that all scientific claims must be understood in context as knowledge-in-action. Quantifiable measure is not a tool to unveil pre-existent knowledge. It is a method that acts creatively in the construction of a system of knowledge; it corroborates, redirects and inaugurates hypothesis while tailoring a rhetorical argument that describes reality. This is to say that the objective measurement of numeric representation in digital technologies emerge as a method to satisfy the need to quantify and standardize bodies, populations and objects of knowledge. The dominance of quantifiable measure as a method for knowledge construction in the modern era speaks about the value of standardization, serialization and calculability as the criteria for symbolic mediations. Conversely, the making of the self and of self-knowledge through data produced by biofeedback sensors, positions the subject into a system of knowledge driven by quantifiable standards. By being in charge of data collection and data correlation, Frederic gains a sense of ownership and control over his sense of self.

The exercise of societal control is also a driving force in James Beniger's (1986) analysis that ties the technological and economic shifts in the American industrial revolution to the contemporary Information Society. He argues that the American industrial revolution generated a crisis in control in manufacturing and transportation and the response to this crisis is another revolution, a revolution in societal control. Beniger defines the control revolution as "a complex of rapid changes in the technological and economic arrangements by which information is collected, stored, processed, and communicated, and through which formal or programmed decisions might affect social control (Beniger, 1986, p. vii*)"*. He argues that meanwhile the production of goods was carried on at a human pace—through handmade manufacturing, distribution capacity tied to the use of draft animals—individual workers could provide the information processing required to control the system of production. With industrialization, the implementation of assembly lines in factories and the railroad system across the country speeds up the manufacturing and transportation of goods and information. The telegraph and the telephone came about as responses to this control crisis because they created more efficient ways to manage the logistics of commerce from distance, through the development of bureaucratic structures and processes that integrated production output, demand and distribution. Early communications networks came to address the first dramatic problems of control. The incapacity to manage the interlinked railroad grid resulted in many wrecks (Ling, 2012). To control the traffic flow, the American Western railroad management instituted a wide range of innovations in bureaucratic organization, programming, information processing, and communication. In summary, the railroad system was turned into a programmable template. Each train conductor followed standardized detailed programs for responding to delays, breakdowns, and other contingencies, who carried a watch synchronized with all others on the line, and who moved his train according to precise timetables.

> They are possibly the first persons in history to be used as programmable, distributed decision makers in the control of fast-moving flows through a system whose scale and speeds precluded control by more centralized structures. This use of human beings, not for their strength or agility, nor for their knowledge or intelligence, but for the more objective capacity of their brains to store and process information, would become over the next century a dominant feature of employment in the Information Society (Beniger, 1986, p. 225).

The development of technologies of communication (telegraph, telephone and later, the internet) are depicted by Beniger (1986) as control technologies that allowed for greater production, distribution, and consumption of goods and services in society. Moreover, they allowed for the creation of a "programmable template" that extended the rationalization of a complex social system from a large scale to global communication to the scale of the individual. The programmable template that oversaw the railroad system was extended in the twentieth-century as a programmable template to manage productive life: punch-card processors, mechanical calculators and (mechanical) analogue and digital computers. These systems setup the concepts of information processing, programming, decision, and control that shapes the social dynamics of the current information age. Beniger's (1986) point is that the implementation of communication networks plants the seed of the organizational infrastructure of the internet and the information society in the twentieth century. Thus, throughout history, the leaps in technological and economic arrangements by which information is collected, stored, processed, and forms of knowledge are created are driven by our individual desires to regain control over the process of production of material, symbolic goods and manage individuals (Beniger, 1986, p. 427).

> Perhaps the most pervasive of all [bureaucratic] rationalization is the increasing tendency of modern society to regulate interpersonal relationships in terms of a formal set of impersonal and objective criteria...[so that] the amount of information about them that needs to be processed is thereby greatly reduced, and the degree of control—for any constant capacity to process information—is greatly enhanced.... [And] the rapid growth of rationalization and bureaucracy...led to a succession of dramatic new information-processing and communication technologies (Beniger, 1986, p. 16).

In Beniger's (1986) perspective, as well as in Foucault's (TEF, 2003), instruments and mechanisms of control are key to regain leverage over social dynamics and over the individual. A state and a market that are organized around bureaucratic processes that certify the individual's identity and measure her efficiency depends on the collection of the individual's information. Personal data collected for example, through census reports and, as discussed in this dissertation, through sensor and pervasive computing technologies, are necessary for personal and societal risk assessment and planning based on data analysis. The collection of personal data by a self-tracker allows the individual to exert control over her own performance and to govern over her body. This exercise of self-control happens in tandem with big data mining that will shape patterns to govern herself and others.

Although the development of the concept of governmentality was not prompted by observing how self-trackers use devices to monitor their physiology and everyday life, the framework developed by Michel Foucault (1997, 2003) is productive to demonstrate how the making of the self is constructed through practices of self-care operated through technologies. Foucault introduces the notion of governmentality (1997, 2003) to explain the practice of self governance that is more concerned with an ethical conduct of the self as a way to care for the subject's well being. In this context, governmentality is "understood in the broad sense of techniques and procedures for directing human behavior. Government of children, government of souls and consciences, government of a household, of a state, or of oneself" (Foucault 1997, p. 82). It speaks of the "autonomous" individual's capacity to exercise self-control and govern over your own actions for self-improvement as a strategy towards ethical behavior. I want to call attention to two aspects in the concept of governmentality that are key to understanding its relevance to the contemporary use of pervasive technologies.

First, that it acknowledges that practices of governance are not circumscribed by the management of the State over populations (as a top-down mode of disciplinary power). In fact, governance is exercised as reflexive and horizontal practices of self-regulation of the individual upon herself and others. Foucault's analysis of the relations of power-knowledge-subjectification is reoriented to a comprehension of technologies of power that is not necessarily localized in the State. When he introduces the notion of governmentality, he is referring not only to the political structure of State governments, but first and foremost, to a broader collection of field of actions that informs way to conduct oneself. Taken in that broad sense, practices of government (governmentality) can be organized through self-governance as a starting point for the government of others. Similarly, through the use of self-tracking tools, the individual monitors and acts on herself to intervene on her physiology, change her own behavior and manage the conduction of her life. Her actions also articulate with other forms of institutional power and generate, for example, recommendations by healthcare associations that define best practices and target values for healthy lifestyles[89], and healthcare policies by insurance companies that feed of personal data to set new baseline standards for premium coverage. The governance of the self, in tandem with the governance of others, are co-constitutive with the technologies of power that enable self-control as they enable control of others.

Second: by expanding the understanding of governance beyond the disciplinary power that is exerted over subjects as a negative form of domination, Foucault also reviews the understanding of power as a productive force of subjectification operated through technologies. I must clarify that Foucault's interpretation of the term technology is not bound to hardware devices or operational tools. Technologies, as apparatuses of power and subjectification, are understood as material processes that govern the behavior of individuals and bodies in ways that incite and drive practices of subjectification. Foucault's understanding of technologies is representative of the system of power

[89] The American Heart Association, for example, recommends that you should walk 10,000 steps everyday to experience improvement in health condition.

relations they operate. In *Technologies of the Self* (TEF, 2003, p.145-169), he describes four typologies of technologies that, interrelated, act in the construction of self for the exercise of governmentality. These four topologies are technologies of production (i.e., how assembly lines produce subjects as economic forces), technologies of sign systems (i.e., how the human body is turned into an object of scientific inquiry by medicine), technologies of power (i.e., how the prison controls the subject's behavior through discipline) and technologies of the self (i.e., construction of identity through practices of self-disclosure and reflexivity). If through disciplinary power, the technologies of power are ultimately exercised on individuals from top-bottom or from outside; with technologies of the self, individuals make themselves the object of their own technical practices. As Foucault (1984) develops the concept of governmentality, he discusses technologies of self with a productive tone, and the self as constructed "in the relationship of self with self, and the forming of oneself as subject" (Foucault, 1985a, p. 6). Technologies of the self are the various "operations on their own bodies and souls, thoughts, conduct, and way of being that people make either by themselves or with the help of others in order to transform themselves to reach a 'state of happiness, purity, wisdom, perfection, or immortality'"(TEF, 2003, p.145). The expansion of the understanding of power as discipline to modes of governance through the technologies of self, introduces another layer to subjectification that operates in the level of what it means to be human.

As I mentioned in chapter two,[90] Foucault searches the Greco-Roman and Christian traditions for specific techniques that humans use to understand themselves. He discusses that the moral principles "Know thyself" and "Take care of yourself" relate to disclosure of truth and asceticism as a strategy for self-accountability. Care for the self refers to an active political and erotic state; self is to be found in the principles of actions and in the political practices. The act of taking care of self becomes reflection about thinking as an activity, of dismounting the truth games and their strategies of representation truth. Constant self-examination, and of the mechanisms that produce truth, leads to the normalization of actions, pleasure and desire. He explains that technologies of the self are the techniques that must be exercised to live an ethical life, through self-knowledge, through self-care and constant examination of actions and understanding of faults.

For Foucault, the self or subject "is not a substance. It is a form, and this form is not primarily or always identical to itself" (TEF, 2003, p. 33). Self means both "auto" or "the same" so understanding the self implies understanding one's identity. Therefore, Foucault's approach to the construction of a sense of self is not aiming at revealing a hidden, authentic and true essence of the self, but it is contingent to a historical ontology of the forms of power that constitute the subject. The relationship between the self and technology enables people to understand themselves as through forms of scientific knowledge, philosophical inquiry, as a citizen... All these technologies produce regimes of truths that produce versions of what it means to be human. Therefore, Foucault's

[90] In which I introduce the Truth or Dare installation, which was inspired by Foucault's discussion of how the self is made/makes herself in the interaction between technologies of the self and the dismantling of games of truth.

approach to technology is not object-centered (a technology is not a self-tracking device). Technology is the material process that produces truth (as an established form of knowledge) about what a self is.

In this chapter, I acknowledge that the self-tracking practices in the Quantified Self Forum and the measuring of truth in the ToD installation are enactments of technologies that produce strategies for self-making. In the case of the Quantified Self movement and the ToD installation, the technologies of self-making are practices of self-tracking and the material process that produces a regime of truth is quantification/digitalization. The rhetorical practice of self-tracking relies on the collection of personal data and the later comparison of this data to pre-established target values. Self-trackers are, for example, constantly positioning themselves in relation to a goal of ideal calorie consumption, duration of deep sleep... They change their behaviour to get themselves closer to the pre-defined goal. At the same time that typical trackers fall into this rhetoric of self-improvement to achieve a better, smarter and stronger self, others challenge this rhetorical system and reinvent the rules of the game. These trackers hack the black-box devices and applications to investigate their inner workings, question the validity of personal data as a representation of their physiology (not in terms of accuracy, but as a system of representation of truth) and develop their own algorithms to correlate their own data. During the Truth or Dare installation, named ironically as "a moral mobile compass for ethical living", the participants had personal data collected and implemented as a parameter to measure the truthfulness of their tweets. The dynamics of interaction with the installation proposed that the participants disclosed personal information so the ToD app is able to assess the truthfulness of their tweets based on physiological response. The practice of asceticism of truth through self-disclosure is one technique of self-governance, as it implies in an “exercise of self upon the self by which one attempts to develop and transform oneself, and to attain a certain mode of being” (TEF, 2003, p.26). The governance of the self requires the knowledge of the self, but also “knowledge of a number of rules of acceptable conduct or of principles that are both truths and prescriptions. To take care of oneself is to equip oneself with these truths: this is where ethics is linked to the game of truth” (TEF, 2003, p.29). When participants trust the ToD as a reliable system of production of truth, the outputs provided by the installation were instrumental to their assessment of their discourse and the discourse created by others. For example, when the participant "Mary" (not her actual name) tweets that the room is dark and ToD assesses the statement as #false, if the user takes the digital output at face value and if it doesn’t agree with her instinctive assessment, she might adjust her sense of judgement to match the machine’s. When participants challenge the premise of the installation, that the algorithmic correlation produces reliable measures for truth, participants interact with it in ways that reinvent the rules of ToD as a truth game. The interaction then is expanded beyond the limits of verification of truth or lie and is turned into a game play of fictional writing.

With this wider context in mind, I describe next the self-making practices that I observed during the Truth or Dare installation and in the discussion forum of the Quantified Self movement. In the accounts of both ToD installation and the Quantified Self forum, the strategies of self-making are dependent upon constructing self knowledge through data collection, data visualization and data sharing in public spaces.[91] In the

[91] Understood as the physical space of the ToD installation, social media in general and the Quantified Self forum website.

Quantified Self movement, users build a sense of self by constructing knowledge about their own physiology, by using sensors, genetic testing and applications as instruments to measure physiological performance. Meanwhile, the participants of the ToD installation construct self knowledge based on the interactions between their intuitive understanding of truth and the measure of truth provided by the app. In both situations, quantification is turned into a fundamental strategy in governance of the self and of others. The wide adoption of sensors and mobile applications demonstrate the necessity to control all life processes and the need to control over the process of self-making. The material discreteness of digital technologies produces an effect of greater accuracy in the measure of physical reality. Therefore, digital applications that monitor how the individual performs physically—when a self-tracker constantly monitors her heart rate—and morally—when participants use the ToD app to verify whether a statement is true—also produce a greater sense of self control.[92]

Self-tracking as self-making

In the Quantified Self forum, self-trackers share their tracking experiments, discuss what to track and which gadgets to use. Consistently, they present a question or a problem they want to solve by collecting personal data overtime and comparing it to other variables and databases. The goal is to learn more about their bodies and environments, while creating processes and databases that allow others to learn about

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[92] J. Macgregor Wise, produces a compelling argument in “Exploring Technology and Social Space” that digital technologies are an enactment of the desire to exercise control over the body and extend its duration in space and time. He explains that within the modern episteme, the standardization of measure of time and space (and how we experience them) follows the realization of the human’s finitude—in Heidegger’s words, ‘Man as a being-toward-death’ (Wise, 1997, p. 6). Technology engages in standardization and measurement of duration of time as an attempt to manipulate not only how time unfolds—to regain control over our own time of existence—but also the becoming of the future time.

themselves as well. Mika Pantzar and Shove (2005) approach practices of metering of everyday life as part of a circuit of reproduction of a logic of quantification that is sustained by a mutually generative connection between measuring devices (i.e. a bathroom scale) and practices of measuring (i.e. weight watching) (p.3). Take, for example, their discussion about the heart meter:

> (…) technological developments in the portability, precision and "accuracy" of heart meters has transformed the realm of everyday calculability. They allow us to "see" our heart (instant feedback), and in seeing, allow us to make adjustments in what we do: they allow us to quite literally tune our own engine. (Pantzar and Shove, 2005, p.5)

Quantification becomes a method of governance of self (Foucault, 1997, 2003), as a "Taylorism of everyday life" (Pantzar and Shove, 2005) emerges as a way to control how the body and the self evolves. In the previous chapter I mentioned Orit Halpern's (2013) description of the smart city Songdo as an algorithmic-driven physical space that is in constant demo mode and for that reason can be continuously enhanced. Similarly, the tracked biological body is put into a position of an eternal beta version. Tracked bodies can be fine-tuned as an engine, based on the responses provided by tracking technologies and our ability to interfere with our physiology.

Some of the tracking practices in the Quantified Self are overruled by an obsession with measuring for measuring, hyped by the release of the latest gadget and its marketing campaign to promote a better, stronger, smarter self. In these situations, self-tracking is a result of a fetish for quantification, in which the users approach self-experimentation as a way to fit within the boundaries of expected performance. In these situations, the user loses perspective of how quantification is established as a system of belief, and take the supposed objectivity of data at face value. One extreme example is the account presented by Jim Ryan,[93] a family doctor who has been caring for a hypochondriac patient who is fixated with quantifiable phenomena. The patient's fixation varies in intensity and shifts from heart rate, to blood sugar levels and other physiological parameters. The patient is constantly monitoring her values to ensure that they are within the expected target values defined by medical associations. While simple self tracking tools have been helpful in providing instant feedback to reassure the patient's sense of self control, at other times self tracking has led to worsen the obsessive behavior.

The use of self-tracking tools produces an ambiguous effect on how the individual constructs her sense of self. Self-tracking allows for cumulative knowledge of how her body performs. As in the situation of the hypochondriac patient, the transcoded data can be approached as given, objective measure that situates how the body performs within a range of target values. In this case, the body is normalized as healthy or unhealthy, and it is up to the individual to execute changes that might impact on the (supposedly) objective assessment. The individual, in this case, falls into a reification of herself as a calculable object. She reacts to target values that define parameters to an ideal subject. Tirelessly, she constantly checks apps to verify if the values captured by the device indicated that she had a good night of sleep, that her heart rate is within the desirable range. In summary, she is constantly keeping score of how her body is positioned within pre-set goals defined by the app's algorithm and the overall self-improvement rhetoric that

[93] https://forum.quantifiedself.com/thread-hypochondriasis-and-tracking

trespasses the control society.[94] By trapping herself into the cycle of numeric validation through self-tracking, she fails to acknowledge the political dimensions that operate the establishment of the parameters she follows. She misses the opportunity to realize that the launch of the 10,000 step quota recommended by the American Heart Association coincides with a campaign that launched pedometers in the market[95]—in fact only after the launch of the 10,000 step program that studies provided evidence of this goal to benefit general health. Because of an obsession with numbers, she gets tunnel vision and for that extreme focus she is likely to excel in meeting the target values, of constantly improving upon her health condition. But she is also likely to lose perspective of the political and technical arrangement that define the numeric parameters she follows. She might also oversee the opportunity to trust her intuitive and sensorial relationship with her body to assess how she feels, regardless of her position within a range output by a tracking device.

The availability of sensing technologies and mobile applications devoted to process personal data has altered the purpose and the frequency of measuring the body's performance. While the monitoring of health and fitness was confined to the medical office, exams and tests were occasional, motivated by symptoms, illness or following a schedule of recommended preventive care. In this case, the access to measuring instruments and their manipulation is also limited and requires the interpretation of an expert doctor. With wearable sensors and mobile applications, the measuring is constant regardless of symptoms and because the measuring tools are user friendly, self-trackers

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[94] In this chapter I discuss how the exercise of control is a heuristics for the production of the self. I expand this further on this relationship in the next chapter when I discuss surveillance and privacy in the control society.

[95] https://blog.fitbit.com/the-magic-of-10000-steps/

can produce information about their own bodies themselves. The wide adoption of sensors and apps does not aim to bypass official medical care, but the possibility to measure health and fitness performance has created greater awareness about the body's physiology. Self-tracking allows for a continuous monitoring of the body in ways that are not necessarily trying to solve a specific diagnosis. Often, the monitoring is broadly exploratory and the act of self-tracking is gathering as much data as possible without necessarily targeting at one specific issue. In the Quantified Self forum, it is very common that users ask others for recommendation of tools and ask for input in their tracking methods. Take this account of the use of a Polar heart rate sensor:

> darko: (...) I'm using the Kubios program to analyze the RR-intervals from my Polar RS800CX. I'm currently doing records of my heart rate variability to show the benefit of a paced breathing at 6 cycle per minute. I know that at this breathing frequency the body goes in a resonant state (the respiration is synchronized with the blood flow) which will laid to an amount of good benefice for the health. Then I'm interested to show how my heart responds to this exercise and how good I perform the exercise. My protocol is as follow: I get in supine position and record during 5 min a baseline measurement. Then I perform a 6cpm paced breathing during 10 minutes and finally I finish the session by recording the last five minutes. Once I'm divided properly the three periods of records in Kubios Software, I save the session in a .mat file. I make this for all sessions. Then I use a matlab script which open each of these .mat files and creates automatically three .csv file for the three periods. All of the parameters we can see

> in the Kubios software are stored in these CSV files in columns. I can then perform easily statistics on these CSV files with any kind of software (...)[96]

Darko's account demonstrates a rigorous, complex routine that he follows in order to gain awareness about how his body performs in these conditions. For Pantzar and Shove (2005), self-tracking is the epitome of the American self-help tradition crossover with a rhetoric of business management (p.4). The quantification of how our bodies perform allows for the metering of everyday life, which in turn provide us with tractable information to solve everyday problems. The practice of collecting, correlating and analyzing personal data provides feedback on how to take better care of the self. As a self-regulating system, the use of measuring instruments allows for self-monitoring and self-improvement. If your diabetes test strips show that your glucose is higher than the target value, you refrain from ingesting sugar and carbohydrates. In this aspect, Mika Pantzar and Elizabeth Shove (2005) argue that "the analytics of daily life is interesting and important because of the part it plays in sustaining, defining and reproducing practice (…) metering is one among other forms of connective tissue that link a) performance and entity and b) past, present and future" (p.2). Quantification, in this sense, becomes an essential tool for governance of the self and of the others as it provides a mutually generative relation between tracking your personal data and setting up statistics of populations. But also, as it is established as a practice of self care, it leverages data collection as an apparatus of surveillance.

The ideals marketed by developers of sensors promise that self-tracking allows us to "take control of your health,"[97] while the technology "connects us with the heart of

[96] https://forum.quantifiedself.com/thread-emwave2-heart-rate-variability-monitor?page=2
[97] http://www.angelsensor.com/

who we truly are, helping us to live healthier, happier and more fulfilling lives while building a brighter future."[98] Quantification and self-tracking are strategies of self-making that are presented as a form of self care that is often implemented through the reification of the subject as a "knowable, calculable and administrable object" (Pantzar and Shove, 2005, p. 4). The mastery of the self over the performance of her own body speaks to the desire to exercise control inherent to practices of measuring.

However, there are also situations in which self-experimentation is conducive to reflexivity about quantification as a process embedded in a circuit of reproduction of practices and technologies, as defined by Pantzar and Shove (2005). In these cases, self-tracking is not limited to an obsession with efficiency. Even though the collection of personal data still aims for gain of leverage over how the body performs, it also relates to curiosity and exploration of the physiology. As an example, see the testimonial the user Dommergaard published about his self-tracking experience. He has been tracking his physical activity, sleep cycle, diet and mood.

> Dommergaard: So far it's been a lot of fun and also a learning experience. The "learning experience" part is not only about what I have logged through my tracking, but also (mainly) about what I have been reading about the subject. (…) I can see a clear progression in my workouts (strength-wise) and can see how my diet affects this (which should be obvious). (…) The mood-tracking (in happiness anyway) is just a gimmick to me and I don't see that as valid data. It sends push-notifications three time a day and sometimes it annoys me, which alters my logging/mood (…) I'm getting more conscious about my body and feel like I'm

[98] http://www.heartmath.com/

> taking control of life—health-wise anyway! At the same time, I can feel IT taking over my life a little bit, but I want to get a lot more data before concluding anything.[99]

When the action of tracking is consequential to the act of exploration, measuring is taken not as an end in itself but as another line of articulation of self. The emphasis is less on technology as a tool and mostly as a process, as a discursive formation that produces a sense of self. In this sense, self-tracking can also be a creative and productive strategy of self-making. When self-tracking is conducted as an open-ended experimentation attentive to its methods and practices, the self-tracker assumes a metacritical disposition to investigate the implications of this close monitoring. This means that the self-tracker is attentive to the outputs presented by the app (that will score her performance based on preset goals) but mostly to the rules that establish the goals. Dommergaard questions the validity of measuring mood and the motivations to quantify it[100].

> Dommergaard: Are we putting up unnecessary rules for ourselves by tracking and monitoring our every move? Are our lives becoming more like videogames—with rules, goals, boundaries and an ultimately competitive nature with self-tracking being the pivot point of our lives?

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[99] https://forum.quantifiedself.com/thread-survey-for-master-s-thesis?highlight=life%2blogging

[100] Medicalization of mental health is the main theme of Michel Foucault's *Madness and Civilization* in which he discusses the emergence of psychiatry. I relate the practices of mood tracking to Foucault's discussion because the implementation of psychiatry demanded the definition of criteria to categorize and separate the ill and the healthy. It seems that through mood tracking we are also evaluating our emotions with the purpose to diagnose them as normal or abnormal. Some emotions and moods that used to be considered as part of natural life processes (i.e. mental confusion and risky behavior demonstrated by teenagers) are now sometimes discussed in the perspective of mental health diagnosis (i.e. ADD). Therefore it seems that mood tracking follows this path of diagnosing unpredictable behavior as abnormal to prompt the self-tracker to address it and be complacent to the social norm.

Dommergaard's comment is representative of other self-trackers who are not taking app outputs as objective "truth" about themselves and often reflect upon self-tracking as a process. In the next chapter I expand on the political dimensions of self-tracking and address the implications of data mining for data sharing, ownership and privacy. I anticipate part of my argument here to state that through the examination of self-tracking practices, followers of the Quantified Self movement become more aware of the political apparatus that sustains data mining. They are attentive to privacy policies and realize that by collecting personal data they are simultaneously feeding big data lakes. All this data is massively aggregated to generate inductive correlations, and big data mining introduces dangers of possibly creating discriminatory correlations. For example, data correlation between symptoms and a disease might lead to better medical treatment but also to inappropriate disqualification for health insurance providers that opt to not cover what correlated data defines as pre-existing conditions. In this sense self-tracking can also be approached critically in ways that call attention to the representational structures that produce truth about the body, normalize behaviors and inform policy.

Earlier in this chapter I presented the context in which quantification becomes a standard parameter for a digital episteme (Maddalena, 2014). My goal with this contextualization was to demonstrate that the parameters that define what it means to be a subject are aligned with the discourses and material enactments that produce what is truth. Differently from the reified status of the hypochondriac, a reflexive position towards self-tracking might foster ethical ways to care for the self's well-being. What defines an ethical approach to self-care (as defined by Foucault) is the acknowledgement that the knowledge about the self is sustained by a strategy of representation of truth. Self-trackers exercise awareness of the dangers that are brought by data mining techniques and realize that every benefit that comes with the use of technology is adjacent to a new harm. Therefore, the construction of an ethical and critical self through self-tracking practices requires the constant examination of the activities to regain control over the procedures that make the self.

The constant examination requires understanding the technical steps of data collection and processing but also taking over the entire self-tracking process when possible. Through amateur genomics testing and metabolism profiling,[101] for example, users collect their own samples and outsource independent labs to run results, or even conduct them at home using DIY kits. Genetic mapping produces a novel perception of our biological bodies because of the co-constitutive dynamics between the biological and computational (coded DNA) domains of knowledge. The field of genetics is highly computational, as it is sustained by the premise that biology can be rendered knowable through code (DNA), that can be broken into discrete units (proteins) and organized into sequences. Eugene Thacker (2004) defines this twofold remediation (Bolter & Grusin, 1999) as biomedia, "as an emphasis on the ways in which an intersection between genetic and computer 'codes' can facilitate a qualitatively different notion of the biological body—one that is technically enhanced, and yet still fully 'biological'" (p. 6). Biomedia is not a thing, but a process of recontextualization of biological and computational components and processes. The computational doesn't act as a tool to represent the biological (as digital pathway to disclose the essence of the biological), but they find

[101] https://forum.quantifiedself.com/thread-list-of-devices-and-apps-for-tracking-your-insides-work-in-progress

themselves recontextualized in an isomorphic relationship where these instances are intermeshed and co-constituted. As a result, self-knowledge ties into the "molecular-genetic knowledge of the body and affects how we understand our own bodies as part of the processes of embodied subjectivity" (Thacker, 2004, p. 6). So, when self-trackers adopt genetic mapping as a strategy of self-making in the fine grain of the molecular level, the notion of self as an autonomously sustained unit falls apart. Take, for example, this account about mapping the body's microbiome:

> Tim Kim: As you guys might have come across the news about how our body is 90% comprised of bacteria and only 10% is our own cells, I was thinking about what that meant for us. If 90% of our body is comprised of community of microbiomes that collaborate with our organs to allow us to function, what is "self" and what does that mean for the quantified "self"? (…) I was just thinking that, if we wanted to quantify the microbiome, it's not really about counting the quantity of all the bacteria but really trying to nail down the complexity of its ecosystem (its inputs and outputs and how it regulates different enzymes and nutrients) (…)[102]

In this case, not only the material biology of the body per se is acknowledged as distributed, but the constitution of self is also is acknowledged as an arrangement of multiple parts. It is more adequate to speak of these formations as fractalized embodiments, as states of becoming; as depicted by the *Deleuzian* imagery of the subject as fold presented in the introduction of this dissertation. This perspective privileges the relational over the predefined form, all bodily existences are in a complex relation with

[102] https://forum.quantifiedself.com/thread-the-future-of-quantified-self

other bodily existences and cannot exist a priori, or autonomously. In this sense, the understanding of how the sense of self is constructed also privileges the emerging event over technological determinism as a negative subjugation.

Games of truth and self-making

The Truth or Dare installation is titled as a "moral mobile compass for an ethical living." The sarcastic title speaks to the centrality of mobile applications in our lives and the dependable relationship we have developed with them, from managing our schedules and contacts to assisting decision making; which route to take, which restaurant to eat. In the case of ToD, decision making has been taken to an extreme. The mock app acts as a proxy to assess the truthfulness of every tweet and reveal the actual intention behind each statement. The premise is that by revealing the truth, ToD allows users to gain greater knowledge about themselves and others, and to make better informed, ethical decisions. The premise that relates truth-telling to ethical behavior departs from Michel Foucault's (1984a) ethical politics, in which the care of the self and the making of the self are linked to self-government and government of others. Drawing from the Greco-Roman and Christian traditions, he discusses how the moral principles "know thyself" and "take care of yourself" relate to asceticism and truth and how finding and speaking the truth (*parresia*) is related to normalization of actions, pleasure and desire. A parrhesiastic speech (in which one truly speaks freely) is an expression of what one genuinely thinks and implicates in a commitment to that truth, to which the person binds herself. The act of taking care of self becomes reflection about thinking as an activity, of dismounting the games of truth and strategies of representation. Taking the Foucauldian (1984a) argument into account, ToD teases out the ideas of subjectivity as practices of governance of the self, and (games of) truth as practices of governing knowledge.

I recover here some of the discussion introduced in chapter two to restate that ToD is an ironic take on self-tracking devices that use physiological transcoded data as parameter of truth to inform about the subject's body and her moral behavior. Foucault (1977) explains that each historical society operates under a "regime of truth," which is the system of parameters that validate

> the types of discourse [society] harbors and causes to function as true; the mechanisms and instances which enable one to distinguish true from false statements and the way in which each is sanctioned; the techniques and procedures which are valorized for obtaining truth; the status of those who are charged with saying what counts as true.[103]

Therefore, truth is a system of "ordered procedures for the production, regulation, distribution, circulation and functioning of statements;" it is linked "by a circular relation to systems of power which produce it and sustain it, and to effects of power which it induces and which redirect it."[104] Subjectification (as the making of the self) is placed in relations of production of power, knowledge and truth. Since power traverses all levels of social interaction, the strategies of construction and validation of truth emerge within power networks and act on—as are produced by—subjectification (TEF, 2003). In this sense that I approach self-making as intertwined in a diagram of power that renders the relationships between self, technology, body, and space. This dynamics breaks from a Cartesian understanding of the "modern" subject that stands removed prior to the social

[103] http://www.scribd.com/doc/22531213/Foucault-The-Political-Function-of-the-Intellectual#scribd
[104] Id.

dimension it exists in. Instead of an independent and autonomous subject, I follow Foucault's suggestion that we must think of subjectivity as a decentralized construction that is formed by several dimensions of the power network.

On the level of the subject, the power network enacts norms and rules that shape the self into a social individual. The individual creates her identity based on parameters and categories that function as a law of truth. She is tied to them. She recognizes her sense of self based on the parameters that define truth, while other individuals acknowledge the validity of these parameters by legitimizing her identity. The making of the self in the situation of the ToD installation takes a moral tone and invites a discussion of how we relate to technology as an objective tool to assess truthfulness.

The ToD app was introduced to the participants as a typical app that promises to deliver better and smarter strategies to navigate an ethical living[105] because its algorithm is capable of identifying true and false statements. The creation of the identity of a liar or a truth teller is created by participants by either validating or challenging ToD's assessment. I observed the different ways in which the participants engaged with the app and related to its premise. Their reactions and tweets evinced that some participants took a critical stance towards the app's premise while others took the app's assessment at face value. I now describe how the diverse interactions inform how a participant articulates the parameters of truth provided by ToD to construct her identity as either a liar or truth bearer.

[105] See Kathy Oswald's (2011) dissertation "Smarter, Better, Faster, Stronger: The Informationalized Infrastructural Ideal" for a comprehensive discussion of how "smart" infrastructures relate to politics of security, utopian and dystopian discourses of informationalization.

While holding the sensors and typing a tweet, the participant looks at the screen and notices how numbers fluctuate, constantly measuring the amount of voltage that goes through her body and with it, her bias towards lying. A loud voice emerges within the small crowd that explored the ToD installation, “Numbers never lie!”. The tweet sent out (figure 20) had been assessed as true by the ToD and confirmed the logical relationship in the statement.

Figure 20: #true statement tweeted through the Truth or Dare app.

The participant had conducted a test to evaluate ToD’s capacity to accurately assess truth. Later, he approached me and introduced himself as a programmer. “Have you thought about using the phone camera to map facial features as well? It would make the app more accurate.” The conversation progressed in a discussion about how to fine tune the hardware, increase sensor precision and integrate the galvanic response skin sensor with the built-in microphone also to monitor conversations. In both exhibits ToD took part of, I observed that this form of engagement with the installation was recurring. The initial interaction with the ToD was often preempted by the question “does it work?"[106] and followed by a test of the functionality of the app. Participants often tested the operational functionality of ToD by tweeting statements that followed logical equivalence reasoning (figure 20) or that they knew to be true—i.e., Dylan says he is 40 #true, I have four siblings #true, I am standing in the carrack #true. The main purpose of the test was to answer the recurring question "does it work?". However, the capacity of ToD to coincide its tweet assessment with the user's expectation of the assessment was not decisive in answering the question. I explain further.

When the assessment produced by ToD contradicted the user's expectation (when a factual, known information was assessed as #lie), participants generally reacted in three different ways. One: by calling attention to the failure of ToD and concluding that the app is not capable of defining truth. Two: by reinterpreting ToD's tweet assessment in a way to reconcile it with their initial expectation.[107] Or three: by acting reflexively about their position in the ToD installation and rearticulating the purpose of ToD from a lie detector to an interactive system that renders fabricated narratives.

The first two situations evidence an instrumental relationship established between the participant and ToD as a technology. In these situations, self-making through technology is dictated by a relationship of control, on which technology is taken as a separate entity that must be mastered by the subject. J. Macgregor Wise (1997) argues that this notion of technology is rooted in a modern episteme founded around the production of dualities—subject/object, space/time, technology/nature—that interact in

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[106] In chapter two I discussed the context of the question "but does it work?" in terms of the participants' expectations regarding the functionality of the ToD app.

[107] In chapter two I demonstrated that even when ToD contradicted factual information, logical reasoning was reorganized to conciliate an acceptable version of truth. For example, when the tweet "the sky is blue" was assessed as false by ToD, the participant reasoned that the rainy weather made the sky look gray at that moment.

an endless relation of control and domination. “Humans create machines to be slaves (to control space, and by doing so controlling time); however, humans are seen then to have been enslaved by their machines” (Wise, 1997, p. 13). The reinforcement of Hegel’s dialectic of Master and Slave echoes the questions of control, either exercised by the subject or acted on the subject, and is what reinforces the cause/effect and instrumental relationship between self and technology. Ultimately, this separation leads to the search of “essentialist” nature of the human and the non-human and reinforces the dichotomy between the human and the other. Such essentialist approach to human and non human natures fails to realize that the strategies of self-making and of truth-making are tied together because “the space of representations cannot be separated from the space of practices and of concepts” (Wise, 1997, p. 17). For these participants, their role in the installation is to provide input and the expectation is that the app can provide objective measure to “invisible” phenomena, such as unspoken intentions and emotions (figure 21).

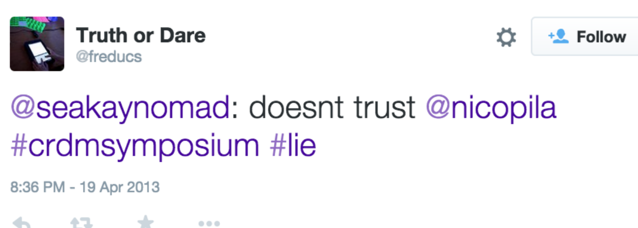

Figure 21: A participant puts a relationship to test using the ToD app.

In the end, the correlative rationality that is created between emotions, discourses and numeric data turns sociotechnical relationships into algorithmic calculations.

Alternatively, for others, the role of ToD is not to confer intrinsic validity to true discourses, but to provoke self-reflection and examine how the strategies of construction of truth also encompass strategies of self-making for those who engage with it. The specific technologies that shape systems of representation that we use to understand ourselves, called by Michel Foucault (2003) as “games of truth” are the strategies that fabricate what is historically defined as truth, as normal, as hegemonic. Games of truth are specific technologies, strategies that shape systems of representation that human beings use to understand themselves. For Foucault (2003) technologies are not confined in the material boundaries of instrumental tools, they are not objects that allow for more efficient and convenient ways to transform the world. They are material sites of political power that act on the formation of self as they are productively enacted by the self in a process for arranging, rationalizing, and manipulating individuals and their bodies. So, the construction of truth and of self emerge through technologies of power, such as the prison, medicine and the asylum, that act on the subject to normalize social control; and through technologies of self, in which the sense of self is positively created through the ethical relationship of the subject to herself (self care), through the govern of self and others.

When participants engage with ToD in ways that extrapolate the notion of technology as an instrumental tool and move past the expectation that ToD would either succeed or fail in providing objective measure for truthfulness, they also acknowledge that the construction of self and truth extrapolate the numeric data output by the app. For this reason, the ways in which these participants engage with ToD acknowledge that self, body and technology are not fixed entities and that the strategies for validation of truth are not fixed representations. As I mentioned previously, the ways in which participants interacted with ToD differed in how they engaged with ToD as a form of self care: either as a tool of control (of production of truth and of how the self is implicated in the construction of this truth) or as a strategy for reflexivity (which acknowledges the sociotechnical arrangement as built in relation to systems of veracity, subjectification and governmentality). In this last case, the act of taking care of self is turned into a reflection about thinking as an activity, of dismounting the games of truth and strategies of representation of truth (figure 22).

Figure 22: Example of tweets that engage is reflexivity regarding knowledge of self and of others.

What is at stake in this later situation is not a binary verification of veracity as true or false, but the construction of a narrative that, while it is not confined by the objective measurement of data (which could only value it as either true or false), still is traversed by it; as it is embedded in a digital sociotechnical assemblage.

The interactive situation shared among hardware, software and users distributes the assessment of truthfulness. When acknowledged, the participant dismantled the objective quality of digital data into the technologically mediated discourses that administer the construction of truth. But even when not acknowledged, the veracity of the statement was always negotiated between the participants and social situation, in which the measured data collected by the sensors and processed by the app was another variable in the situation, but never the definitive answer.

It might seem that self-making through ToD and through self-tracking are different, as ToD measures morality by assessing true/false tweets and self-tracking more commonly measures physiological variables. But they both belong to and are tied into a regime of production of truth based on the premise that transcoded physiological data and data aggregation might reveal truths that conduct the construction of the self. A self that utilizes sensors and mobile apps as a compass for self-improvement by either taking their outputs at face value or by challenging them; but in both cases engages with technologies to better care for her body and mind as an individual and to construct her identity.

Conclusion

In this chapter I discussed how a data episteme acts through the aegis of control to devise practices of self-making. In the accounts of both the ToD installation and the Quantified Self forum, the strategies of self-making are dependent upon constructing self knowledge through data collection, data visualization and data sharing in public spaces.[108] In the Quantified Self movement, users build a sense of self by constructing knowledge about their own physiology, by using sensors, mobile applications and even genomic mapping to measure physiological performance. Meanwhile, the participants of the ToD installation construct self-knowledge based on the interactions between their

[108] Understood as the physical space of the ToD installation, social media in general and the Quantified Self forum website.

intuitive understanding of truth and the measure of truth provided by the app. In both situations, there are instances in which the making of the self is overruled by the objectification of the subject into an administrable body for optimal performance. Similarly, the interactions with ToD that engaged with the app in terms of its operational functionality, by either blindly trusting its effectiveness or being intimidated by the truths it might reveal, also demonstrated a sense of self that is subjugated by technology.

Alternatively, there were also circumstances in which participants engaged with ToD in ways that extrapolated the instrumental verification of binary measures of truth. In these situations, participants dismantled the notion of truth as objective and disclosed the belief system of construction of truth via ironic and humorous tweets. In the Quantified Self forum, users provided accounts that describe self-making as an experimentation, in which the sense of self is territorialized and de-territorialized through multiple articulations of transcoded biological data.

This chapter reinforces the argument presented in the previous chapter in acknowledging a data episteme as a driving force for the construction of knowledge in the Internet of Things. Through measuring and tracking the self, pervasive computing technologies are adopted as technologies of self-governance. While they allow for the individual to exercise self-care and to experiment with novel ways of self-making, the digital infrastructure also subjects personal data to be collectively aggregated and analyzed. Hence, the self-regulating individual, while deeply engaged with strategies of self-making, is also feeding aggregated data into macro-societal governance projects.

In the final chapter of my analysis, I discuss how the governance of the self unfolds into the governance of others, through the scaling of personal data to large sets of big data. Data mining is founded upon the aggregation of personal data to generate analytics that produce a collective picture of a social body and foment policy and regulation. I describe how self-trackers and critical makers deal with the implications of big data mining in terms of surveillance dynamics and issues of privacy. I conclude by presenting the strategies they develop to resist and rearticulate politics of data accessibility and sharing.

CHAPTER FIVE

Power

"Raw data now!" Sir Tim Berners-Lee[109]

"Raw data is both an oxymoron and a bad idea; to the contrary, data should be cooked with care". Geoffrey C. Bowker (2005, p.183)

Measuredme contacted other users on the Quantified Self forum to clarify some doubts about his personal data and right of use:

> Measuredme: Has anyone made their personal quantified-self data public? I mean not just charts and/or analysis, but actual "raw" data. If yes, did you include any kind of legal disclaimer on how people can and cannot use data, etc.? I am asking because I just made my September data available for download but have not included any formal statement of limitations. Did I just open "pandora box"? Technically, I can't apply Creative Commons license to quantified-self data, because it was obtained empirically, and was not "created." Or can I? [110]

The responses varied. Some users suggested that the cost of restricting the use of the data could exceed the benefits brought by the protection of the dataset, others discussed more extensively on the benefits of a creative commons license and the possibility of a contract per use, and some even questioned the desire and necessity to control how the data set is being used for. To this user, Measuredme responded:

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[109] https://www.ted.com/talks/tim_berners_lee_on_the_next_web

[110] https://forum.quantifiedself.com/thread-what-disclaimer-should-i-use-when-making-my-personal-quantifiedself-data-public

> I don't care about the METHODS for visualizing, correlating, and disseminating data and insights, but I do care about MOTIVES behind the analysis and the IMPLICATIONS that third-party is making based on the results.[111]

The argument provided by Measuredme regarding the use of his personal data demonstrate that the concern with data privacy is not related to its accessibility. He is comfortable with the different ways in which his raw data can be processed and visualized, but feels insecure about the purposes that might motivate data appropriation. In a personal scale, data misappropriation is dangerous because it can reveal intimate information about the individual, and when correlated with other datasets, creates narratives that shape the identity by establishing associations that she did not predict.[112] In a global scale, the aggregation of personal data leads to data correlation for predictive models that are often portrayed as facts.[113] While algorithmic analysis is an efficient strategy to process large amounts of data, it also carries a dangerous misconception that data is a "more accurate" representation of reality, and that the larger the data set, more precise it is in describing the phenomena. These misconceptions reveal main points of concern. The assumption that digital data is impartial and objective makes the automated

[111] Id.

[112] A now famous account about data correlation is of an aggravated parent that submit a formal complain to the retail store, Target, because his teenage daughter had received discount coupons for maternity items in the mail. The girl received the coupons because Target had recently implemented a new purchase recommendation algorithm on their website; the algorithms looks at the user's browsing history to suggest products. Target apologized to the worried father only to get another apology from him later on, because "there had been some activities going on in his household he wasn't aware of" and his daughter was actually pregnant. One of the features of Target's algorithm is the calculation of a "pregnancy prediction" score that estimate the shopper's due date to within a small window, so coupons can be timed to very specific stages of the pregnancy.

[113] A post shared on the Uber blog in March 26, 2012 (http://newsroom.uber.com/) entitled "Uber data, the ride of glory" presented correlated data of Uber's customer base to determine the frequency of one-night stands. One-night stands were identified based on correlating information about the use of Uber between 10pm and 4am on a Friday or Saturday night, followed by a second ride from within 1/10th of a mile of the previous nights' drop-off point 4-6 hours later. The original post has been deleted but accounts are available in different sites such as https://gigaom.com/2012/03/26/uber-one-night-stands/

algorithmic predictions equivalent to the truth. The capacity to collect and process data is unequal between individuals and institutions, therefore, their power to produce truth about themselves and others is also asymmetric. I expand on these points further.

The paradox of current data collection processes is that self-tracking and data mining are co-constitutive, similar to what Tom Boellstorff (2013) calls a “dialectic of surveillance and recognition.” The pervasiveness and extension of data mining is constant, sometimes insidious, as the current data-centric society relies on data collection to establish algorithmic correlations. On the other hand, self-trackers rely on the outputs of more extensive correlations to define performance goals. Surveillance, in the current state of the information age, is framed as a form of belonging, often exercised through disclosure of personal information. The Quantified Self post mentioned exemplifies one of the threads that demonstrate conflicting sentiments regarding how surveillance is operationalized and for which purposes data is collected. Other threads also show divided perspectives regarding policies of open privacy; while some users advocate for complete availability of data, others are more resistant to it. Because of this complex co-dependency between data collection, sharing and correlation, the negotiation of parameters of privacy is also complicated. The discussion on the table is not to opt between sharing or not sharing data, either making it “public” or “private.” It is not a matter of controlling data access, but discussing the extension of data usage. Once personal data is available, how can the user maintain control over the use of their personal data; which power dynamics are being enforced through the correlations that are being produced and which positions are being undermined. The negotiation of privacy implicates in the comprehension about how knowledge is being produced through data correlation and which power relations are being privileged.

In chapters one and three I demonstrated how digital data permeates our social structures and discussed how data mining constructs a way of knowing reality through aggregation and correlation. As digital infrastructures become the standard mode for collection, storage and exchange of information, our activities, our bodies, finances, etc. are consistently transcoded to numerically discrete, correlatable and scalable units of data. Because digital data is materially discrete and can be described mathematically, digital objects are in fact algorithmic arrangements of the same basic units. The transcoding of the physical world and actions into data leverages diverse human activities into manipulable information that can be correlated and reprogrammed into other digital objects. Because the volume of data is ever-growing and data is abstract, our brains alone are incapable of processing big data (Andrejevic, 2013). We must rely on mechanisms of artificial intelligence to identify patterns and reterritorialize floating data into bodies of information. For self-trackers, for example, the use of graphs and charts is essential to identify trends that will inform them about how their actions effect on their physiology. For health insurance companies, the access to personal data is economically relevant because of what data correlation might reveal in terms of health risks. Although we are all immersed in a data-rich environment and so much of our social structure is mediated by digital technologies, this scenario can be misleading in terms of portraying a symmetry of data access and processing capacity. The levels of access to data and the capacity for data processing vary between a self-tracker and a health care organization. Pervasive computing technologies and techniques of big data aggregation and correlation reinforce the existing inequalities of data access. In this aspect, Mark Andrejevic (2014) calls attention to a big data divide, which I discuss further, that marks the powerful position of those who own and manipulate data mining in contrast with the powerless situation of those who are targeted by data mining.

In chapter 3, I explained that data aggregation and analytics is a key factor for the scalability of hybrid spaces in the Internet of Things; from the micro scale of the biological body to the macro scale of social politics. Then in chapter 4, I demonstrated how the collection and sharing of personal data devises practices of self-making that operate under the aegis of control to govern the self and others. In this chapter I answer my third research question and address how the use of pervasive computing technologies to monitor the individual, her physiology, and online practices rearticulates practices of surveillance and produces new boundaries for privacy and intimacy in the Internet of Things. To do so, I recur to recent scholarship in surveillance studies (Haggerty & Ericson, 2000; Andrejevic, 2013, 2014; Raley, 2013; Mann, 2003) to explain how data mining reconfigures the Orwellian surveillance model to a model that operates as a surveillant assemblage (Haggerty & Ericson, 2000). As a technological enactment of a society that operates under the aegis of control (Deleuze, 1997), a surveillant assemblage brings about new dangers: invasion of private communications, public disclosure of inferred facts, and possible harm arising from false conclusions about individuals based on profiles created by big data analytics.[114] To counterpoint these dangers, I identify the strategies being developed by self-trackers to positively resist forms of surveillance and

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[114] The United States Council of Advisors on Science and Technology (PCAST) released a white paper in 2014 with policy recommendations to regulate practices of big data mining in the country and undermine the risks mentioned. The report is available at https://www.whitehouse.gov/blog/2014/05/01/pcast-releases-report-big-data-and-privacy.

to negotiate privacy. I focus specifically on accounts presented by users of the Quantified Self forum and critical makers, and discuss how they engage with technology, policies for data sharing, and collection.

A surveillant assemblage

As a practice for governance of the self and others, self-tracking provides a mutually generative relation between tracking your own data while feeding big data lakes. Because of this dialectical relationship it leverages data collection as a mode of surveillance. However, the surveillance that is implemented through self-tracking and big data mining differs from Orwellian models of surveillance. Traditionally, surveillance is discussed as a kind of disciplinary power being imposed from top-down external forces that coerce individuals to behave in a certain way (Foucault, 1978). In *Discipline and Punish*, Foucault (1978) looks at the organization of the penal institution to describe how punishment has been transformed into mechanisms of disciplinary surveillance and control over individual bodies. Discipline, as a technique of power, is intimately related to the rise of a productive economical subject (*bourgeoisie*) and of democratic states that require internalized mechanisms of surveillance and control to exercise its command—now justified also as a mechanism to provide the security of the population. This mechanics is materialized in the panoptic architecture of prisons, which allows guards to observe the behavior of prisoners but doesn't reciprocate the privilege of visibility to the latter. The panoptic gaze watches over the incarcerated individual, but it cannot be looked into the eye—"He is seen, but he does not see; he is the object of information, never a subject in communication" (Foucault, 1978, p.200). The schema of the panoptic is an efficient surveillance mechanism because prisoners cannot tell whether they are under surveillance or not, they are coerced to obey the rules faced with the possibility of punishment if caught in undisciplined behavior. The invisibility of the surveiller and the visibility of the surveillant guarantee the automation of disciplinary power. The functioning of power is automated because the panoptic surveillance cannot be verified, therefore it is assumed as always underway.

Foucault argues that the panopticon must be understood as generalizable mechanism of disciplinary power that spreads to other institutions beyond the prison. It is implemented in institutions that deal with a multiplicity of individuals on whom a particular form of behavior must be enforced. They are schools, to instruct children, factories, to supervise workers, and it takes shape in the institution's hierarchical organization, in specific procedures, postures, timetables that must be followed and in consequence produce obedient and docile bodies. The panopticon functions as an abstraction of the originary source of power. That is, the notion of power shifts from one that is imposed from the hands of the monarch to one that is dispersed through institutional apparatuses. In the 19^{th} century, modern age panopticism is integrated into several types of institutions (educational, manufacturing, medical, etc.) and subtly pervades social practices. As such, the panoptic surveillance sets expectations for social roles (the teacher as a locus of authority and the obedient student) as much it as creates a bureaucratic faceless modality of power. Disciplinary power is naturalized as the vocational purpose of institutions. It is the mechanism that strengthens and amplifies the social forces to make individuals more productive, to spread education, and to normalize behaviors.

Foucault recognizes that disciplinary societies and panoptic surveillance are transient forms of exercise of power that are historically localized in the eighteenth and nineteenth century. Gilles Deleuze (1997) follows Foucault's historical approach to demonstrate that the twentieth century post-industrial capitalism brings about different power dynamics. Control over individuals is decentralized and pervasively distributed beyond institutional enclosures because the rigid institutional structures described by Foucault (the prison, the school, etc.) are in crisis. The rapid changes in consumption and production required these institutions to be in constant reform. As Deleuze describes, post-industrial societies are more fluid and forms of control are quickly adaptive. Disciplinary power surveils bodies of individuals as workers in the factory, students in the school as reified objects within a social enclosure. Control in the post-industrial society encourages the interconnectedness over these spaces as a strategy to extend and amplify its agency over individuals.

> In the disciplinary societies one was always starting again (from school to the barracks, from the barracks to the factory), while in the societies of control one is never finished with anything—the corporation, the educational system, the armed services being metastable states coexisting in one and the same modulation, like a universal system of deformation. (Deleuze, 1997, p.4).

Control acts on and traverses the environments in which the individuals inhabit "like a self deforming cast that will continuously change from one moment to the other, or like a sieve whose mesh will transmute from point to point" (Deleuze, 1997, p.6). The conception of a control mechanism that underpins all social dynamics takes on an integrated programmatic approach in which all parts are variations of the same theme. In the corporation employees are “motivated” to achieve ever-rising performance targets for merit based salaries; education is extended outside of formal degree programs and continuing education is turned into another mechanism to feed the perpetual machine of self-improvement. The focus in the control society is the continuous modulation of the universal structures to maintain the production and consumption of goods in motion. Therefore, the power dynamics at play in control societies do not fit into a hierarchical, punitive, unidirectional mode of panoptic surveillance but shift in a continuous, limitless modulation. Mark Poster (1996) calls this never ceasing machinery of surveillance created by databases as a super-panopticon. Due to the pervasiveness of the super-panopticon in technological infrastructures, it produces subjects who are willingly contributing to their own surveillance by sharing personal data. Subjects are formed in the arrangements of data elements and for that, the produced subjects are also fractalized. If surveillance in disciplinary power was executed by looking at the object of interest, in the control society monitoring occurs through ordering the discrete pieces of information about the objects of interest. There is no direct gaze over them, but there is constant information collection, correlation and analysis of the articulated parts they are in interrelated with. Deleuze describes Guattari’s vision of a near future that is now here:

> Felix Guattari has imagined a city where one would be able to leave one's apartment, one's street, one's neighborhood, thanks to one's (dividual) electronic card that raises a given barrier; but the card could just as easily be rejected on a given day or between certain hours; what counts is not the barrier but the computer that tracks each person's position—licit or illicit—and effects a universal modulation.

Guattari's description is a perfect fit with the model of smart city discussed in chapter three and the description of Bill Gates' smart house described in chapter one. In the perspective of the smart grid, the subject is her id number and the password she uses to activate behaviors in the system. The city/house responds by granting or denying access to spaces and controlling her relationship to that space. In this respect, the interactions between the city and the subject described by Guattari and the effects of control described by Deleuze share the same modular dynamics of self-tracking and data mining. Data fragments of "dividuals" inhabit dynamic databases that are accessed to retrieve biometrics, physiological information, financial transactions, browsing history… all sorts of actionable digital traces that can be reconfigured to shape a subject's profile. As Deleuze remarks, "the numerical language of control is made of codes that mark access to information, or reject it. We no longer find ourselves dealing with the mass/individual pair. Individuals have become 'dividuals' and masses, samples, data, markets or 'banks'" (1997, p.5).

The concept of the dividualized subject is critical to the understanding of how control and surveillance are currently put in practice because the material organization of digital technologies is sustained by the same modular logic. The individual body transcoded as data is no longer a totalizing unit. Through practices of self-tracking, an individual's body is deterritorialized into bits of data. In a personal level, a self-tracker uses algorithms to reterritorialize this data into meaningful information (through graphs and comparison of historical records) and produce knowledge about her own body for the exercise of self-governance. But in the perspective of big data analytics, the personal data produced by an individual is irrelevant in isolation. The reterritorialization of this data for the production of knowledge does not target a specific body. Instead the purpose of data mining and correlation is to contribute to the cumulative growth of databases, for the "progressive and dispersed installation of a new system of domination" (p.7) that veers towards a free-floating dynamism of control.

Based on this differentiation, Kevin Haggerty and Richard Ericson (2000) explain that contemporary surveillance is rhizomatic (Deleuze & Guattari, 1987) because "it has transformed hierarchies of observation and allows for the scrutiny of the powerful by both institutions and the general population" (Haggerty & Ericson, 2000, p. 617). They define surveillant assemblages as operating in the intersection between various media that are driven by the desire to bring systems together and combine practices and technologies into a larger whole that can be interconnected for diverse purposes. "As it is multiple, unstable and lacks discernible boundaries or responsible governmental departments, the surveillant assemblage cannot be dismantled by prohibiting a particular unpalatable technology" (Haggerty & Ericson, 2000, p. 609). In a sense, the surveillant assemblage implements the dynamics of a control society within a data episteme, enacted through the creation of digital forms of data collection and aggregation. I insist that the practices of collecting and analyzing data pre-exist the emergence of networked databases and practices of automated collection and correlation. The example of manual and mechanical data processes by the U.S. census presented in chapter three demonstrates this argument. However, it is undeniable that digital technologies have increased the speed and capacity of data processing, and redirected the goals of this process towards predictive analysis.

The surveillant assemblage is enacted through innovative techniques of control, in which individuals willingly take part of because enrollment implicates in achieving higher capacity of self-care, self-development and social engagement. Take for example how self-trackers track and share their fitness milestones in social media. Running a 5k and posting the map of the route with data about distance and speed; starting a diet and posting pictures of the meals and the weight loss record. Active monitoring over how the body's performance produces actions of accountability, which is then legitimated or questioned by others. Rather than being watched from a focal point above (the sufix *sur*, in surveillance, means "above"), we are embedded in an algorithmic matrix of data collection.

To explain this inversion in perspective, Steve Mann (2003, 2004) introduces the term *sousveillance* ("watch from below"). Mann focuses on the creation of wearable technologies (mostly cameras) to leverage the opportunities for inverted surveillance, lateral observation and personal sharing.[115] While traditional surveillance is characterized by organizations observing people, the use of wearable technologies (cameras and other sensors) inverts the top-down vigilance allowing individuals to surveil the surveillers (citizen photographing the police), as well as themselves (through self-reporting) and each other (sharing of lived experiences). Mann (2003) recognizes an activist potential in the appropriation of wearable technologies because they enhance the individuals' capacity to access and collect data about their surveillance, counter-act and neutralize it. The repositioning of technologies of surveillance has created new opportunities for multi-directional forms of data collection, thus making sur/sousveillance increasingly intertwined.

[115] See the evolution of Steve Mann's wearable prototypes at http://wearcam.org/

The latest forms of surveillance also differ in practices of observation. Bentham's prison model that inspired Foucault's (1978) panopticism reproduces the notion of the Big Brother—the omniscient eye who sees everything. Hence, the practice of surveillance is that of visual scrutiny of the eyewitness. With the distribution of multiple sensors and the extension of the digital grid into physical spaces, the nature of "observation" changes. I summarize the main aspects that define these changes. First, surveillance is decentralized and distributed. There is no Big Brother watching closely over specific individuals, but there is a network of surveiling technologies (discreetly) gathering information about all individuals, all the time. Second, the focus of observation is not only visual, it occurs in multiple senses. Take the model of the smart city discussed in chapter three. Multiple sensors are embedded into physical spaces to capture data about noise levels, traffic, air quality, temperature, etc. The data collection occurs also in the personal level (and its correspondent metadata) and tracks how the individual physiology performs as well as how it interacts with that physical space. And third, the multiple practices and technologies that take part on the surveillant assemblage are not targeting a body as a way to mold a specific individual. The current forms of surveillance entails in the continuous collection of (meta)data for unstated nor preset purposes. It goes beyond scrutinizing a targeted individual as it penetrates every fiber of social fabric (Andrejevic & Gated, 2012). As I argued in chapters 3 and 4, these disperse flows of data are rearranged to identify trends and establish unimagined correlations that will inform predictive analysis. The body, the social behaviors and the practices that construct a sense of self is transcoded into digital information, so that it can be rendered as discrete, comparable and scalable.

> Today, however, we are witnessing the formation and coalescence of a new type of body, a form of becoming which transcends human corporeality and reduces flesh to pure information. Culled from the tentacles of the surveillant assemblage, this new body is our "data double," a double which involves "the multiplication of the individual, the constitution of an additional self" (Poster, 1990, p. 97).

Data doubles circulate in a host of different centers of calculation and serve as markers for access to resources, services and power in ways which are often unknown to its referent (Haggerty & Ericson, 2000, p. 613). In this regard, the surveillant assemblage acts as a territorializing and de-territorializing machine, as processes of data collection and aggregation parse out traces of data and renders visualizations of data patterns. Mathew Fuller (2005) clarifies that the big brother surveillance, that is visually imperative, is replaced by a "socio-algorithmic process" that calculates "flecks of identity." The purpose of surveillance then shifts to constantly gather series of digital data that break down every trail and trace of our actions; from our browsing history to geolocation and physiological information. Transcoded bodies and the identity of individuals are fragmented into bits of data and flow into data lakes and into the cloud. When a query is run by an algorithm, maybe from a private company looking to do targeted advertising or from counter-terrorism units looking to anticipate terrorist attacks, these broken fragments are put together to form a composite profile of a potential consumer or a potential threat. To this regard, Rita Raley (2013) comments that dataveillance[116] is not simply descriptive (monitoring) but also predictive (conjecture)

[116] Rita Raley states that the term dataveillance was originally coined by Roger Clarke in "Information, Technology and Dataveillance," Communications of the ACM 31 5 (May 1988) to define a a data based surveillance system that at that time was in his opinion already "technically and economically superior" than the CCTV reality depicted by George Orwell.

and prescriptive (enactment) (p.124). Above all, data mining and analysis are performative actions with concrete manifestations in the world. Discrete data sets are correlated to reterritorialize our data-doubles into a composite profile that can be targeted for intervention. These interventions can be manifested as practices of self-care when, for example, a self-tracker changes her sugar intake to meet a glucoses target value; and also as measures to ensure safety when, for example, TSA attempts to use data analytics[117] to profile passengers and potential threats on flights. Raley (2013) concludes, “the composition of flecks and bits of data into a profile of a terror suspect, the regrounding of abstract data in the targeting of an actual life, will have the effect of producing that life, that body, as a terror suspect” (p. 128). The danger in the current form of surveillance is not the possibility of punishment (as in the disciplinary model). It lies in the incapacity to humanly grasp the complexity of data correlations and understand how they draw the line between safety and risk. Moreover, in the conflation between data correlation and production of truth, moved by an alleged objective nature of data.

Big data is not neutral. One of the dangers pointed by the United States Council of Advisors in Science and Technology[118] regarding big data mining is the discriminatory potential based on automated profiling. In chapters three and four I argued how data analytics is a form of statistical knowledge that provides a rational basis for the construction of social reality and the self’s identity. Algorithmic analysis looks for trends

[117] See TSA’s call for white papers on how to integrate commercial data with their current pre-screening program at https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=5f3d932eeef30941d0fc945a5c14346f&_cview=0 As of February of 2015, phase 3 of this program (live testing) has been put on a hiatus as phase 2 (prototyping) is being expanded.

[118] Available at https://www.whitehouse.gov/sites/default/files/microsites/ostp/PCAST/pcast_big_data_and_privacy_-_may_2014.pdf

and patterns in big data to establish relationships between variables that can be reassembled as profiles. My physiological data, paired with my financial history, immigration records, and social media profiles is aggregated with many other sources to construct an idea of who I might be, what I might buy, to calculate if I am at risk of violating my visa status... My profile is conferred the qualities and the assessment of risk possessed by others that are statistically similar to myself. As a neo-liberal individual engaged with production and consumption of goods, I am calculated and ranked according to variables that will define my buying power (through a credit score), my housing possibilities (mortgage values, interest rates), and I will have my actions associated to my ethnic background and race. For example, Propublica, a non-profit newsroom, conducted a research about how pricing of online services changes based on geolocation.[119] Their findings indicate that indeed service estimates are higher if the zip code entered belongs to neighborhood with a higher income demographic. However, they also found that when the variable race/ethnicity is taken into consideration, Asians are almost twice as likely to be offered a higher price for online tutoring services than non-Asians, regardless of their zip code. The algorithmic relation created for the proxy of race replicates the stereotype that Asian parenting is strict and focused on academic success than other ethnicities, thus potentially a more profitable audience for online tutoring services.

In this sense, data analytics is in its logical premise discriminatory, as its goal is to divide data sets and attach values to individuals based on similarity. But it can be dangerous when the parameters that define the correlations perpetuate biases that endures

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[119] http://www.propublica.org/article/asians-nearly-twice-as-likely-to-get-higher-price-from-princeton-review

irrational prejudice and social and economic inequality. Latanya Sweeney (2013), former Chief Technologist at the Federal Trade Commission, demonstrates how Google AdSense also operates based on racial bias. She used Google's search engine to search for hers and other first names that were previously identified as more commonly assigned to black persons, such as DeShawn, Darnell and Jermaine. The ads fed back to the search results were suggestive of arrest records in 81% to 86% of the cases. When searching for names such as Geoffrey, Jill and Emma (names that were previously identified as more commonly assigned to white persons), the word "arrest" appeared in ads 23% to 29% of total searches. She concluded that Google's AdSense algorithm exposes racial bias in society and that the parameters used to build the algorithm can reinforce this bias. I explain further.

Google's AdSense measures the effectiveness of targeting advertisement based on the click-through rate. Imagine an employer, a bank or a leasing office conducting a background check on an applicant. When the user clicks on an ad that suggests a criminal history tied to a name search, it relates to the algorithm that this correlation is relevant. Thus, the relationship between traditional black names and the keyword arrest is reinforced and the algorithm tends to offer similar ads in future events. Solon Barocas and Andrew Selbst (2015) remark that discrimination may be "an artifact of the data mining process itself, rather than a result of programmers assigning certain factors inappropriate weight". The behaviors forged by the technological protocols of the algorithms mimic the values of social dynamics. But the overt discrimination by big data analytics is even more problematic because "data mining's ill effects are often not traceable to human bias, conscious or unconscious" (p. 4) which might give the impression that they are naturally part of the system, and are thus acceptable.

The setup of data analytics models might replicate a discriminatory bias from its inception and impact negatively historically disadvantaged populations. As evinced by Sweeney's (2013) study of targeted advertising, when the correlated data points to a relationship between variables (demonstrated by when users click on keyword "arrest" ads when searching a name), a "model" is created to track the historical variation of these variables. "Black-sounding name" and "arrest" are turned into an entity of interest (named as a "target value") to be observed. It is up to the data miner to interpret the relevance of emerging target values and to specify their application. This is a critical point in which the subjective interpretation of the data miner defines the relevance of a target value to the goals of the search. The fact that data correlation is automatically processed does not divorce it from human made decisions. For this reason, the programming stage of the algorithm is not merely instrumental; it is a critical process that must take in consideration how human interaction might feed into machine learning.

In the following sections I address the dangers diagnosed by self-trackers to forms of data collection and correlation. The discussions in the Quantified Self forum demonstrate concerns regarding who owns data collected by proprietary applications, the possibilities of personal data being appropriated by third parties in ways that might put the self-tracker or others in disadvantage. I discuss how trackers negotiate privacy in a context in which data sharing is critical for the establishment of big data and address the forms of resistance developed by them and other critical makers to ensure that their data is being used in ways they are in agreement. I articulate the issue of personal data sharing with data ownership, and how self-trackers relate to raw data as an alternative to break the opaqueness of "blackbox" applications. And finally, I analyze how self-tracking practices and DIY making of sensors and apps constitute a form of amateur science that might empower users.

Negotiating privacy: Data ownership/access/sharing

"Fear of surveillance is high, but what if societies with the most openness develop faster culturally, creatively and technically?"[120] This question opened a discussion about a hypothetical scenario of a data transparent society in which all personal data is accessible, and sharing personal data is the norm. The discussion took place during the Quantified Self European Conference in Amsterdam in 2014 and was carried on to the online forum. The online discussion was summarized by Laurie Frick, a data artist who explores patterns of self-tracking in data visualizations. Laurie Frick is a firm believer in an open data policy and a post-privacy society where all personal data collected about a person should be available, especially to enable new apps, new insights and research. She comments about the implementation of this hypothetical scenario: "a place to start is to have individuals the right to access, download, view, correct and update data about themselves. Seems a much more healthy way of actually knowing what is gathered about you, and for those of us who care taking some ownership of it."[121] Laurie Frick's optimism regarding open privacy bets on data as a source of self-knowing that trumps the "vaguely unpleasant" surveillance:

> Data collected about us will unfold a personal narrative and story to reveal a hidden part of us we are trained to ignore, a way to know ourselves and anticipate

[120] https://forum.quantifiedself.com/thread-breakout-is-open-privacy-the-next-open-source
[121] http://www.lauriefrick.com/blog/?offset=1403089343000

> what comes next. Perhaps seeing the abstract patterns and rhythms of your self-tracking data is a short-cut to mindfulness. A quick and dirty way to boost your immune system, the benefits of meditation and self-reflection without much effort.[122]

Her rationale sustains that if data surveillance is inevitable, we might as well embrace it, experiment with it and appropriate it in ways that are beneficial to self-awareness and compelling to our sense of self. Her optimistic view is shared by other enthusiastic self-trackers—hence the growing numbers of adopters of self-tracking—but the boundaries regarding data privacy are clearly being disputed. For example, out of the 21 progressive self-trackers (as described by Laurie Frick) that participated in the discussion about privacy that took place at the Quantified Self Conference, only 3 were for a data transparency, open privacy model of data sharing. While this is a small sample faced with the total number of self-trackers, other discussions in the Quantified Self Forum demonstrate that many users are insecure about the implementation of an open access policy.

> RobertNess: I think insurance companies are the biggest concern when it comes to health data privacy. But others argue we should forget about privacy in this space, especially considering how easy it is to get samples for genetic or other molecular testing. Forget your boss reading your iPhone health data, how far are we from company toilets that steal your metabolome and microbiome? (…) One think that people do not consider is the unexpected ways the data can be used, some of which might be quite unwelcome. An example is Uber's Rides of Glory blog post

[122] http://www.lauriefrick.com/blog/will-a-data-selfie-boost-your-immune-system

(…), where an Uber blogger wrote about using Uber data to track one night stands. It is reasonable to expect Uber to try and figure out your riding trends, perhaps predict when you will want to ride. But it is a surprise, and for most an unwelcome one, when Uber starts actively infer behavior you consider deeply personal and outside the domain of their stated mission of providing a taxi service. (…) Even if it doesn't directly relate to the core business, that kind of explanatory analysis is a great way for a data modeler to build an intuition for the data and the stories it can tell.

Ejain: Can't judge a service's competence without doing some kind of audit, but things like use of secure connections, handling of password resets, responsiveness to bug reports etc. can be a good indicator. Judging a service's trustworthiness is harder: What is the business model? What is the revenue and valuation of the company?(…)

Berdelyi: Agreed. I think transparency is important and really a site/service needs time to demonstrate their trustworthiness and competence. Not always the best option, but external services that provide seals can be useful to consumers (…)[123]

Questions arise regarding who owns the data, and in consequence, who decides how it is being shared and for which purposes it is being aggregated. Also regarding issues of access; how to know when data is being collected and who has access to it? Even though the concern regarding data privacy has shifted from government to corporate surveillance, the asymmetry of data access between the average self-tracker and the corporation keeps the individual in a powerless situation regarding data ownership

[123] https://forum.quantifiedself.com/thread-mobile-health-and-fitness-apps-privacy-study?

and control. Auto insurance companies, such as Progressive,[124] are already using tracking devices to monitor how insurance holders drive and adequate insurance prices. Snapshot, is a device offered by Progressive that can be installed in the car to measure driven distances and record date and time stamps. An independent report written by Civil Rights activists entitled "Civil Rights, Big Data and our Algorithmic Future"[125] calls attention to the potential rise of insurance costs for low-income individuals. They argue that underprivileged populations, many of whom are people of color, are more likely to work the night shift and drive longer distances between home and work. Automated data analysis might conflate the data of late-night workers with late-night party goers and assign to this first group the same risk assessment of late-night, possibly intoxicated drivers. The added cost of insurance does not only reflect the possibility of a night-shift worker to be hit by a drunk driver, but in the eyes of the insurer both profiles are conflated as carrying out risky behavior in the same degree. Responsible night drivers will pay more for car insurance than will responsible daytime drivers.

Health insurance companies are also moving towards the adoption of wearable tracking devices to better assess risk. Companies that offer health insurance benefits encourage employees to wear fitness wearable devices (as part of a "corporate wellness program") to hold staff accountable of their health. The most common fear regarding the use of health tracking devices is not that data is being collected, but that it can be repurposed by

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[124] https://www.progressive.com/newsroom/article/2011/march/snapshot-national-launch/

[125] The report was written by Aaron Rieke, David Robinson and Harlan Yu from Upturn, with the support of Alethea Lange, Erica Portnoy and Joshua Tauberer with financial support from the Ford Foundation. The report's outreach and rollout was coordinated by Jennifer Calloway, Michael Khoo, and Stephanie Vanegas from Spitfire Strategies; and Scott Simpson from The Leadership Conference on Civil and Human Rights. It is available at https://bigdata.fairness.io

health insurance companies and used as parameters to increase the cost of insurance premiums. Health insurance companies are reinventing their formula to calculate underwriting requirements through predictive models. Documents from a presentation given by risk assessment consultants about the advantages of data correlation demonstrate how health insurance companies are using data not intentionally disclosed by the applicant to calculate their premium cost.[126] The presentation demonstrates that traditional underwriting requirements (health history, credit information) are time consuming and inefficient. Through aggregated data from “non-traditional sources,” such as online purchase history and social media posts, providers are able to identify habits and preferences that are significant to the assessment of the health status of the applicant. Does the applicant use fitness tracking devices and what does her fitness report inform about her health state? Has the applicant bought cigars online? These habits, often shared online on social media, take part in the calculation of the applicant’s risk profile. While the data correlation might adjust fairness of insurance holders that have a perfect bill of health (and might not make use of the services), it might overcharge those who are close to the margins of acceptable health condition (who are in fact in greatest need of the services).

Self-tracking devices are so widely used, and other sensors are already so prominently available that a discussion about privacy in this scenario must not limit to a choice between either making data private (only the user accesses it) or public (everyone accesses it). The Internet of Things is only sustainable because it is data creative and data dependent, therefore a either/or approach to data sharing is counterproductive. For the

[126] Alice Kroll & Ernest Testa, Predictive Modeling for Life Insurance Seminar (2010), presented at the Society of Actuaries Seminar. Available at https://www.soa.org/files/pd/2010-tampa-pred-mod-4.pdf

issue of privacy to be productively addressed, the privacy rhetoric beyond a feature that can be turned on or off, as a setting that allows for data to be kept secretive (the user maintains control over it) or made public (the user has consented sharing). It is required to discuss how privacy can be exercised in ways to grant to the consumer/citizen/individual tools to manage how her personal data is collected, shared and repurposed.

Privacy rhetoric often focuses on the perspective of the neoliberal individual and the Western Post-Enlightenment notion that the individual is the “smallest indivisible unit of personhood” (Dourish & Bell, 2011, p.141). For this reason, privacy is often discussed through an individual-centric lens, as a given right to control over information at the expense of the collective. de Souza e Silva & Frith (2012) also call attention to this rhetoric by bringing examples of how users interact with location-based services. Foursquare, for example, provides economic and social incentives for users who “check-in” in business via coupons and network visibility. Sharing information is portrayed as a beneficial trade-off because the economic benefits outweigh the possible consequences of disclosing personal data. However, the negotiation of privacy extrapolates this symbolic currency exchange. Privacy is culturally constituted (Dourish & Bell, 2011), contextually negotiated based on parameters for sharing, and in an era of social media and data gathering algorithms, it is also networked (boyd, 2012). The negotiation of privacy entails managing visibility, articulating with networks and dealing with large volumes of data. Privacy is not defined as a utilitarian action to restrict access to a piece of information. It is about building strategies to maintain control over how shared information is received and interpreted. dana boyd’s (boyd, 2012; Marwick & boyd,

2014) research on how teenagers use social media demonstrates how they negotiate privacy based on this understanding of networked privacy. Teenagers disclose personal, locational information and manage instances of publicity and privacy by choosing what to share, whom to share it with, and through which platforms to disclose it. They build relationships with people and social media platforms based on shared trust, a sense of safety and intimacy. They also develop tactics to bypass parent monitoring over their internet use (either technically or by using slangs and cultural references they won't understand) and make their posts public, while at the same time semantically private. As sophisticated as these tactics may be, they do not prevent algorithmic analysis; these teenagers will still receive targeted ads and their actions will corroborate a digital version of their identity. boyd (2012) concludes that these teenagers are simultaneously sharing information online while working on ways to achieve privacy in networked spaces, without necessarily relying on holding total control over the data they generate. Privacy, in this sense, is about context and networks, constant monitoring and filtering social media disclaimers. It is not only about controlling what data is being pushed out, but being aware of what drives data correlations and managing the flow of information.

The comments on the Quantified Self forum demonstrate that there is a general concern with privacy issues and deliberate efforts to exert control over how personal data is shared. In order to exert control over the use of data, self-trackers implement various strategies. One way to better understand how information is being collected and appropriated is by gaining knowledge about which privacy policies data collecting devices and apps abide by. In order to better grasp the implications to data privacy of

Quantified Self related services, a group of self-trackers started a forum topic[127] to parse out how privacy is being negotiated. Users have scrutinized the privacy policy terms to answer:

1. Can you control who has access to your data? Can your data be shared with (or even sold to) third parties (other than law enforcement) without your permission?

2. Can you export your data? Can you get your data out of the service with a simple download, or through an API?

3. Can you close your account? How difficult is it to close an account? What happens to the data after an account has been closed?

4. Can the terms change without prior notice? Do you have a chance to close your account, if the terms are changed and you no longer agree?

5. Can I trust them to keep my data secure? Does the service take basic measures to keep your data secure, such as supporting (or, better, enforcing) the use of secure connections (HTTPS)?[128]

In a collective effort, users answer these questions and create a database of how each device and app approaches data privacy. There is a willful investment on understanding how data is being manipulated by corporations that develop the technologies they use. For this reason, users also get involved with third-party non-profit initiatives to call attention to these issues. A study conducted by Clearinghouse, a non-profit dedicated to consumer education and advocacy, surveyed the privacy risks for 43

[127] https://forum.quantifiedself.com/forum-data-ownership-privacy
[128] https://forum.quantifiedself.com/thread-terms-of-service-privacy-policies

mobile health and fitness apps[129] with the support of the Quantified Self community. The study points that data collected and shared by these apps is usually unencrypted, and thus vulnerable; many apps connect to third-party sites without user knowledge; 72% of the apps presented medium to high risk of data breach (32-40% chance of invasion); and that the "safest" apps are paid (because they don't rely on advertising, it is less likely they will share the user's data). Users also contribute to other initiatives such as Open Notice,[130] an organization that seeks to standardize privacy policy terms, and Common Terms,[131] an initiative that is trying to solve the problem that nobody reads terms of agreement by developing terms in a more accessible format.

Another strategy that is also implemented by self-trackers to exert more control over how data is being shared is focused on network security. Because most sensors and apps communicate wirelessly and data is stored in the cloud, there is a legitimate concern regarding the security of these. Some users have found alternative ways to track themselves through open source hardware and software that do not require online storage:

> vancityboi: I'd love to start measuring everything I can about myself, but I'm a fan of privacy and trying to keep my information out of the cloud. Where would I go for a list of apps (phone, desktop/laptop) that keep the data on the local device?
> Domainkiller: I struggled with the offline vs. cloud issue for 6 months while I built my "track all the things" app I call Nomie. I'd be curious to hear what you think about it http://getnomie.com I'm about to roll out beta 2 which is completely

[129] https://forum.quantifiedself.com/thread-mobile-health-and-fitness-apps-privacy-study
[130] http://opennotice.org/
[131] http://www.commonterms.net/

> removed Beta 1's need for "the cloud." Now, it's offline first option of syncing with any couchdb compliant server.
>
> Ebivan: @vancityboi, I know how you feel. I wanted to buy a tracker even before they we're available, but I never got around to do so because of my privacy concerns. Finally, when Snowdan *[sic]* came through last year, I got even more paranoid. I turned back to using (mostly) linux pcs, tweaked my phone for more privacy and begun using encryption where I could. But would love to track myself anyway! To my latest knowledge, there is only one tracker on the (German) market, that doesn't require mandatory cloud access to store data. But this one doesn't let you export data from the phone.[132]

This post illustrates a recurring situation for self-trackers. When faced with a discordance about how a sensor or an app collects data, how data is processed and protected, trackers reach out to the community to gather recommendations for best privacy practices, and are often advised about the differences in data privacy between an open source accelerometer datalogger and a proprietary fitbit. Or, when technically capable, users take the initiative to develop open source data aggregators to analyze their own data.[133]

Another topic of recurring discussion is the access to raw data. Proprietary devices often limit data exchange between the sensor and device and do not provide the user with native data. In consequence, data visualization is limited to the parameters established by the software. See, for example, this review by Laurie Frick regarding the emWave brain frequency monitor device:

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[132] https://forum.quantifiedself.com/thread-separation-of-cloud-vs-local-storage

[133] See http://www.openyou.org/

> They hide the actual data collected and present colored thermometers and visual charts, but don't give you actual HRV data (…) I want access to data that I can compare everyday, and emWave masks your data in a proprietary "coherence" chart and hidden algorithm.[134]

Self-trackers that are more seriously invested in self-monitoring opt for devices and apps that will allow for raw data access, which will be correlated and analyzed through parameters defined by the user. The purpose of self-tracking is to enable access to data that otherwise would not be available. When proprietary devices and apps are unclear regarding how data is collected, analyzed and provide limited options for visualization, the sense of agency and ownership over the data is undermined. I discuss the implications of raw data next.

The critical aspect on how self-trackers negotiate privacy is that the strategies they implement enact their expectations regarding how personal data is collected, aggregated and repurposed. Their agency in the establishment of privacy policies for the Internet of Things is defined by their political action in appropriating devices, scrutinizing their policies, and developing tactics to bypass policies when not in agreement with them. Their actions establish practices and parameters that define ethical behavior regarding personal data sharing and how personal data is commoditized by corporations and governments.

Empowerment through raw data, critical making and amateur science

In 2009, Sir Tim Berners-Lee led the TED talk[135] audience on the chant "Raw data now!" to ask for governments and enterprises to make their unaltered data available

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[134] http://quantifiedself.com/guide/members/259/Laurie+Frick
[135] https://www.ted.com/talks/tim_berners_lee_on_the_next_web

over the Internet. His expectation is that the access to raw data will reveal an unlocked potential of correlations that the current version of the web conceals and leverage data access centered in institutions and governments to citizens. His proposal of an open linked-data web aims at the creation of an ever larger depository of information, but mostly at the availability of data in a native standardized format that can be algorithmically parsed out and that is shared through an open data license, so it can be reappropriated. Through the availability of raw data made available through a new version of the internet (where all data is linked in its native format), Sir Tim Berners-Lee believes that democratic engagement will be revigorated, as citizens hold governments accountable for their actions. Open data will foster scientific collaboration and innovation, which in consequence can generate economic growth. But can raw data really fulfil this expectation? Is raw data the holy grail to empower the end user? I argue that opening up data is not sufficient to leverage the asymmetric data power between users, institutions and governments. I agree with Mark Andrejevic's (2014) analysis of a big data divide that suggests that the ethical complications of big data mining cannot be solved through merely granting data access. Data access is one of the steps to diminish the divide between data rich and data poor, but is not limited to it. Even if all data is globally made available natively, the processing resources differ between individuals and institutions. There is also an issue of media literacy. The big data rich also possess the computational skills required to read and write code, which sets up another hierarchy that opposes those who interact with data through a graphic interface and those able to interact directly with the code. A gender divide is also existent, as most code proficient users are male. More than granting data access to female programmers it is necessary to address the greater issue of gender inequality in the field of STEM disciplines. Thus, data power entails in multiple approaches beyond data access; one key factor being the individual's technical capacity (or availability to resources) to correlate and analyze data. Edward Snowden's exposure about the NSA's practices of routine surveillance reinforced the need for transparency in data collection processes by governments and institutions. It also demonstrated the corrupt interdependency between the institutions collecting data and the agencies that are supposed to regulate them. The leak of Snowden's files, along with previous leaks from Julian Assange, come to reinforce a general distrust regarding how institutions make use of data mining and the need to set up multiple courses of action to leverage the data playing field.

Institutional distrust is shared by self-trackers who often opt for open platforms over proprietary technologies. Quantified Self users also share some of Sir Tim Berners-Lee expectations regarding how raw data might empower their position in relation to a big data divide. But their tactics to counter act their position of disadvantage compared to opaque data processing also try to address some of the issues that Andrejevic (2014) brings up. Self-trackers discuss extensively about how to bypass "blackbox" applications and retrieve raw data, export formats and how to sync data from various devices in one main aggregating platform. They also acknowledge that raw data is complex, difficult to interpret and that proprietary algorithms can be resourceful in leveraging the data to an intelligible level. However, their clear preference for raw data is founded on the fact that raw data enables greater flexibility in terms of analysis, in addition to being native and unaltered. While technically this "nativeness" means that users can manipulate source files with minimal computational overhead; socially and culturally it conveys the idea that raw data is more authentic than other types of data. The pretense objectivity of digital data and the representational and preemptive accuracy of big data predictive models enable a big data hype that Kate Crawford (2013) calls a “data fundamentalism” and José van Djick (2014) refers to as “dataism.” The hype with raw data and big data models becomes problematic when data is conflated with automated truth, or prediction of truth; as a predictive model that is bound to happen as demonstrated by analytical correlation. If raw data is taken as more legitimate and data correlation as “closer to the real”, the information that comes forward is dangerously turned into automatic truth. I don’t mean to imply that the demand for raw data is unjustified; when in fact it demonstrates how self-trackers are aware of the mechanisms of data processing, and that they are willing to push the boundaries set by corporations to take ownership of their data and control over how it is manipulated. But the claim for raw data cannot profess big data’s preemptive and predictive power as a contemporary version of an oracle. One must consider that still in its nativeness, raw data is performative. It is performative in a discursive level, because data is modeled in digital code, and follows the procedural and symbolic dynamics of language. “Data are not facts, they are “that which is given prior to argument” given in order to provide a rhetorical basis” (Gitelman, 2013, p.7). Also, in the cultural level, as I argued in chapter three, data are cultural objects that materialize forms of knowledge that are historically constituted. And finally, in the machinic level because in order for raw data to be actualized, algorithms must perform actions. As much the operation of algorithms are previously determined and their actions may be predictable, their behavior are open to error and their outcomes gain uncertainty as the level of complexity of data processing increases. “Blackbox” devices and applications mask the visibility of data processing, but the fixation with raw data is equally blinding.

As self-trackers extract personal data from devices, and correlate their numbers using open platforms, they also venture into prototyping hardware and software. In the Quantified Self forum, the range of expertise level varies: from software engineers and developers who work with wearable devices and use the forum to get feedback on them, other developers that are involved in self-tracking as a hobby, to beginner level trackers who are curious about the types of data these devices can return. While this later group frequently asks questions about which app to use to measure something, the other interactions are highly technical (for a non-programmer). They discuss preferable languages, libraries, exchange scripts and collaborate with each other in developing stages and beta testing. If self-tracking grants users a sense of data ownership when it makes personal data available to them, when these users venture into making their tracking devices and applications themselves, the level of ownership and power over the data collection is even greater. The recovery of this sense of power is a critical factor that motivates self-trackers to develop their own approach to self-monitoring. By doing so they attempt to diminish the gap between the big data divide (Andrejevic, 2014) that separates the “data rich,” those who own and have access to sophisticated and opaque data mining techniques (search engines and other enterprises), and the “data poor,” who do not own the same capabilities for data collection and feel powerless faced with the complexity of the dynamics of data processing.

When self-trackers and critical makers deconstruct the operations of data collection conducted by proprietary devices and applications, they are actively negotiating their privacy boundaries. By getting deeply involved in how data is being collected and processed, they are in fact claiming a position of power in relation to how these processes are conducted by corporations. Critical making and hacking are creative actions of resistance and freedom that try to disrupt the current status of power distribution and diminish the big data divide. I follow Michel Foucault's (1997, 2003) approach when I speak of actions of resistance as productive and affirmative, in opposition to the common understanding of resistance as reactive and negative. Because of the relational dynamics between power-knowledge-subjectification, resistance does not exist outside of power. Power is everywhere, diffused and embodied in discourse, social practices and regimes of truth. Whenever there is power, there is resistance. In every scale of the social body, a multiplicity of forces of resistance animate, shape and create the power dynamics of the social body, extending it from intimate and reflexive self-knowledge to scientific discourse and social norms that act on the individual. The goal of resistance is not the liberation and the overcoming of power structures, but the constant rearticulation of power relations in ways that shifts the power balance. I perceive the actions of hacking, critical making, and the DIY initiatives by self-trackers as active struggles to disturb the established social-technological protocols (Galloway, 2004). Protocols are the power conduit of the isomorphic relations between the code, as an ontological, political and technological category and the praxis, as a set of procedures and actions. A technological protocol (TCP/IP, DNS in the case of the internet) is not only a figure of control of the network (that reigns in the distributed nodes and connections) but is also the set of rules that operates it.

Self-trackers, makers, and hackers come up with alternative solutions to proprietary technologies by exploring the protocological breaches and bending the protocols in a different direction. By doing so, they are not breaking free from the protocological sphere, or transcending power, once the network simply does not exist outside of the protocol that renders it. “Protocological struggles do not center around changing existent technologies but instead involve discovering holes in existent technologies and projecting potential change through these holes. Hackers call these holes exploits” (Galloway & Thacker, 2007, p. 81). Resistance is productive in the sense that through a tactical appropriation of technology, self-trackers, makers, and hackers are creating alternatives models of production and circulation of symbolic and material goods. Hackerspaces, makerspaces and the many variations of the emergent alternatives spaces for technology critique and production—discussed in chapter one—are not anti-institutional. In fact, through government funding, private grants, and the creation of start-ups to produce and distribute open hardware and software, they are gaining institutional contours themselves.

The reshaping of protocols through DIY, hacking and critical making are tactical behaviors that, as I explained in the previous chapter, also aim to care for the self. Self-trackers are often more focused on self-care through monitoring of health, time and activities. Critical makers, as I mentioned in chapter two, are more involved in the political agenda of technology and in reflecting upon the process of making. However, when self-trackers take on the role of self-making through technological experimentation (not only technology adoption), they experience the possibilities and affordances of quantified measures, and ultimately are challenged to look at self-monitoring beyond the mechanics of devices. Some accounts by self-trackers demonstrate an outstanding level of rigor and complex methods in the conduction of experiments. See the experiment conducted by OP Engr on heart rate variation:

> OP Engr: Hi FuChieh Hsu, I have real time data, but it is raw RR numbers, not a graph. Even so I followed the approach of inhaling when I noticed RR starting to drop and exhaling when RR started to rise. I captured my heart within about a min. The result was a doubling of HRV based on the Poincare plot SD1 and SD2 results using RR feedback. Also my Low Frequency power went from 40% to 90% (Kubios analysis) using RR feedback. My results were comparing the HRV using just relaxation breathing against RR feedback. Both measurements were sitting. I need more experiments to determine the benefit of doing this technique. By the way I did the RR approach first so this capture effect seems to extinguish very quickly. I also don’t know how far you can pull the natural heart rhythm using breathing at a different rate. I also looked at the difference between lying down, sitting, and standing for taking the measurements. Standing gave the lowest SD1 result (visually good correlation to position). The SD2 was not a good an indicator of position. Exercise tended to lower both my SD1 and SD2 numbers in the short term (limited sample size).[136]

This account is one of many that demonstrate how experimentation in the Quantified Self can indeed be comprehensive and reflexive regarding the method of data collection as well as in the implications of the findings for a construction of a sense of self. Although the focus of this dissertation is set on the appropriation of pervasive

[136] https://forum.quantifiedself.com/thread-emwave2-heart-rate-variability-monitor?page=3

technologies, self-trackers also use other methods that are not dependent on sensors and apps to experiment and better understanding the working of cognition, physiology and keep track of habits. Discussions about nutrition, use of nootropics, genomic mapping are also present and along with sensor and apps compose an extensive dataset about these individuals. Self-trackers independently outsource lab exams with blood work, hormonal, and genomic tests that would traditionally be mediated by a doctor. Certainly these processes are not to replace the role of the physician, but they allow for more knowledgeable patients. However, as I argued earlier in this chapter, the access to "raw data" —in this case, the numeric values of protein, hormones, etc.—is not sufficient to process a meaningful analysis and create relevant knowledge about the physiology. As much as sensors and wearable technologies become widely available, an individual self-tracker will not have similar technical processing capacity nor the interpretative skill set as a medical doctor. Self-trackers do however, strive to diminish the asymmetric knowledge balance by conducting independent research.

> Skyline: I am going to study an area related to QS (e.g., biochemistry, bioinformatics, genetics, nutrigenomics etc.). I would like to study the area that can have the highest impact on self experimentation by increasing my ability to understand and use research while increasing my awareness of how the body's biology works. (…)
>
> Winslow Strong: Hi Skyline, I have similar aspirations, and am currently self-educating in the areas that I am most interested in, which are: self-experimentation (properly done), anti-aging, cultivation of good mental states,

increased mental performance (through meditation, nootropics, dedicated practice, SRS, etc.), and strength training. And of course the scientific areas supporting these. (…)

Skyline: Hi Winslow, I have self studied a lot of areas like strength training, nutrition, etc. over the years—however, this remains "on the surface" because I basically rely on other people I find to learn from—books written, blog posts etc. from people I find to be rigorous in their analysis. At times however there is not information out there available - and/or the views of what is right is conflicted or still emerging. At that point I'm limited by my lack of understanding of biochemistry, genetics and other areas to push forward. That way I can access the research and dissect it myself and confirm analysis or create ideas/ hypotheses to test of my own. Currently I have a few biochemistry books that I'm working my way through—but I'm wondering if it would be useful to attend an online university course to get more "regimented" learning. Probably the most useful would be to get closer to people actually practicing biochemistry in the labs and perhaps get involved myself. [137]

Through tactical modes of knowledge production, in ways that bypass tradition institutional knowledge, some self-tracking practices blur the lines with amateur science. The Quantified Self movement itself functions as a platform of resources where trackers share their experiments, recommend literature and collaborate to create alternative forms of scholarship. Self-trackers articulate forms of resistance through strengthening

[137] https://forum.quantifiedself.com/thread-related-studies-to-qs-what-will-be-most-helpful?

consumer literacy regarding privacy policies of applications, devices and services providers, and also by gaining more insight into the paradoxical dynamics of data mining. As a community, self-trackers rely on recommendations from other members and build their own databases of resources of best practices, which devices and tools to use, and methods of data collection and aggregation. They also present accounts of their experiments and ask for critical analysis of their tracking methods and results, and by creating records of their experiments they establish their own scholarship.

These tactical activities that are conducted by self-trackers do not aim to overcome traditional forms of knowledge (physiology) or institutional power (medicine). I follow Raley's (2009) tactical analysis of new media to reinforce that the negotiation of power does not aim for a transcendental transformation of the self or for an ethical program created upon a rhetoric of an emancipatory human agency. The reconduction and reshaping of protocols are tactical behaviors towards healthier and ethical power relations in the networked society. The keys to re-empower individuals in a data-centric society is to increase media literacy by revealing the operations of data collection and aggregation, and position users with infrastructure capacity to run data processing.

Conclusion

In this chapter I addressed how the power dynamics in the Internet of Things, specifically in practices of self-tracking, are articulated as a surveillant assemblage. Distributed surveillance requires individuals to establish new tactics to negotiate boundaries for privacy and to create forms to leverage control within the network.

Self-trackers are constantly trying to break the "blackboxed" devices apart. Literally, when they build new prototypes and algorithms to analyze the data; and figuratively, when they investigate the motivations, the business models, and terms of services of the devices they use. As they are invested in reengineering their own bodies, they are also invested in claiming ownership of the reengineering process. Between the disclosures and shutting down of protocol breaches, the self-trackers see themselves oscillating in different roles. When surrendered to the complexity of the technological system they become what Vilém Flusser (2002) calls employees of the black box, incompetent selves of deciphering the protocols strategies and reconstituting the abstract dimensions of the strategies. An employee is one who does not invest in power, but lives in it, perceives it as truth and does not manage to apprehend the ideological forces that adapts it. When an effort to decipher the becoming of the technical diagram disrupts the protocol and bends it in a new direction, self-trackers come across alternative games of truth (Foucault, 2003). They start producing their own narratives by constructing their own algorithms, by hacking into the hardware and rearranging their internal operations. They realize that the apparatus and its protocols are imbricated in deeper layers of conceptual, technical and political ramifications. The challenge of the exercise of critique, as Foucault (2003) reminds us, is that since criticism is a discipline that investigates the activities of the (wo)men, it seeks the understanding of the (wo)men themselves. Self reflection does not imply in taking the self as an object, but realizing that there is a concomitance of the relation subject/object and the construction of the experience of reality. The reconduction and reshaping of protocols are tactical behaviors towards healthier and ethical power relations because it requires the assessment of the current relations of production, signification and power, and fosters the possibility of refocusing them.

CONCLUSION

This dissertation started by investigating how the embeddedness of networked connectivity onto things, physical spaces and biological bodies rearticulates embodied spaces in the Internet of Things. Personal data collection and big data mining traverse all dimensions of life and creates forms of knowledge that integrates data embodiments of multiple scales: Personal data from an individual individual creates a data double of her physiology; data lakes of traffic patterns, consumer habits, are correlated to create a demographic data double of a neighborhood. I discussed how self-tracking practices—founded upon a digital episteme (Maddalena, 2014)—render forms of subjectification and produce arrangements of power. Through a materialist approach to technologies, I acknowledged that the material organization of digital media is paramount to the forms of knowledge that are produced through them. Through the observation of online discussion in the Quantified Self forum and through the construction of the ToD installation, I highlighted how self-tracking practices produce quantified knowledge about the body that expresses social and cultural identities of individuals. Personal data produced by a physiological tracking app produces an identity of a (un)healthy body; the GSR data processed by the ToD installation informs identities of liars or truth tellers.

In the introduction of this dissertation, I explained that by adopting a genealogical perspective to the Internet of Things I intended to produce an analysis that is attentive to the material affordances of pervasive computing technologies and the power forces of the practices they render. This approach reconciles ongoing scholarship in the fields of Digital Humanities and Critical and Cultural studies in the investigation of media technologies and networks as a procedural material articulation of discourses, social practices and actions. Secondarily, this approach also complements functional perspectives to the study of technologies presented by fields of Computer Science, which are mostly focused on the progressive enhancement of the interface functionality. My research questions were defined in relation to the embeddedness of networked sensors and computers in physical space and the biological body (how are embodied spaces produced through the appropriation of pervasive computing technologies?); subjectification (how does the use of pervasive computing technologies devise practices of self-making?) and power (how does the use of pervasive computing technologies produce networks of power?). These questions emerged from auto ethnographies on adoption of self-tracking devices and gained a more defined contour as I engaged with the making of the “Truth of Dare” installation and with the observations of the Quantified Self forum.

In chapter one, I presented a history of the Internet of Things as emerging from three overlapping programs: the research and development initiatives in ubicomp and pervasive computing at companies such as Xerox and IBM; the research agenda at academic institutions such as MIT’s *Bits and Atoms*; and grassroots tinkering movements with physical computing prototyping in hacklabs, hacker and makerspaces. I argued that the current state of the IoT is driven by the social imaginary of calm computing introduced by Mark Weiser (1991) that predicted a technological future in which the infrastructure is seamlessly embedded in physical spaces and naturally integrated with social practices. It has been almost 25 years since Weiser published *The Computer of the 21st Century* and the frequency in which our smartphones freeze, the Bluetooth does not sync and the short life of our devices' batteries demonstrate that infrastructure might never be completely go unnoticed—although technology development aspires such goal. I demonstrated that the IoT is an ever expanding aggregating network marked by a heterogeneity of platforms, business models and competing protocols. I identified three infrastructural shifts that contributed to this setup. First, a material shift in size of computing hardware, which allowed for micro and nano computers to be embedded into physical spaces, bodies, and things. Second, a shift in accessibility, with greater affordability of proprietary hardware, availability of open hardware/software options, and expansion of internet infrastructure through wireless connectivity. And lastly, a shift in distribution, as crowdsourced and public funding supports grassroots movements such as communities of makers and hackerspaces and popularizes DIY approaches to technologies as well as the adoption of open access microprocessors, micro-controllers and sensors in everyday life.

The innovative drive of the IoT also emerges from the context of grassroots experimentation with technology and critical theory. While experimentation with technology in the context of R&D departments of industry is structured around scheduled phases of a project, budget and prototyping as the main goal; in hacklabs and other communal technology spaces, experimentation is more open ended and speculative, based on emergent creativity and forged by the limitations of resources, but without a clear goal set beforehand. In this perspective, critical making emerges as an emblematic research method for social studies of technology, in ways that acknowledges the broader social context of technology appropriation. Critical making comprehends reflexive material engagement with technologies, attentive to the making process and focused on emerging questions and issues that might inform broader social implications of technological practice.

In the second chapter I presented an account of the critical making process of the installation "Truth or Dare: a moral mobile compass for ethical living." I described the technical setup of the installation and addressed the critical reflections that emerged during the hardware construction and code writing. The experimentation with galvanic skin sensors (that measure the voltage variation in the body as a parameter for emotional distress) highlighted the complexity of the biological and computing interfaces. I approached the interactions between participants and the ToD as interfaces built upon embodied actions and production of space (Farman, 2011). I consider sensors and other pervasive computing technologies as cultural devices where the interface is not a surface or a threshold that defines the limits of the human and the computational, but a milieu of cultural practices encoded in digital form (Manovich, 2001). Practices of self-tracking and the technological arrangements they organize are enactments of parameters for knowledge production, and cultural practices. Therefore, they are foundational aspects of the becoming of our selves and the ways in which we are inscribed in the world. The translation of electric impulses to binary codes, command lines and preset behaviors between the sensor, the processor and self-tracking practices are not only parallel and simultaneous, but also contingent and co-constitutive.

In chapter three I articulated how a data episteme (based on a model of a digital epitome introduced by Maddalena, 2014) produces strategies of knowledge construction that is organized through the collection, modularity and correlation of aggregated data. I acknowledge that the underlying logics of big data mining is determinant to spatial practices in the Internet of Things. Big data mining is not only defined by the size of data sets, it is defined by a dynamic flow of diverse, flexible, fine-grained, relational data (Kitchin, 2014). Big data is collected, kept unstructured and schemaless in data lakes to enable customizable data analysis and processing. Due to the level of complexity, it can only be processed through algorithmic intelligence. Big data mining is future oriented; what big data aspires for is the predictive power to arrive at correlations that otherwise could not even be intuitively imagined. The possibility of any data becoming relevant at any time, depending on the identification of a pattern, is what justifies the commitment to collect all data at all time, aiming for "total information awareness" (Andrejevic & Gates, 2014).

I analyzed different arrangements of embodied data as topologies of hybrid spaces (de Souza e Silva, 2006) to explain how the pervasiveness of data mining practices produce articulated embodiments of personal data and predictive models of correlated data. I presented a matrix of three topologies of hybrid spaces articulated in terms of (1) form of data collection and processing (actionable, automated or sentient), (2) the pervasiveness of data mining practice (mobile, embedded or invasive into the bodies of people, things and spaces); (3) the type of interface (screen-based, haptic or through biometrics/sensors); (4) the type of action-to-knowledge (tracing physical space, data sensing/correlation and predictive models); and (5) the physical platform of access (external device carried by an individual, wearable attached to a body, or integral part of bodies). The first topology emerges from the intentional and actionable generation and collection of data by the user. In this topology, data collection occurs when intentionally initiated or allowed by the user, such as self-reported data collection through location-based networks. Examples of this topology can be found through spatial annotation practices using smartphones to access location-based services, such as Foursquare. This type of technological appropriation for spatial practices has been widely discussed in scholarship about urban mobilities and mobile media (de Souza e Silva, 2006, de Souza e Silva & Frith, 2012, Sheller & Urry, 2006, Adey, Bissell, Hannam, Merriman, Sheller, 2014, Goggin, 2006, 2008, 2011). The second topology is marked by automated data collection from wearable devices with haptic interfaces, such as fitness bands and heart rate sensors. In this topology, location is complicated from geolocation in physical space to also traverse the internal space of the body. Personal data collection as described by followers of the Quantified Self movement is a typical example of this topology. By accumulating physiological data, individuals trace patterns in the data sets and hybrid spaces are constructed as “data doubles” of their own bodies. They are constituted in the interplay between the users’ physical bodies, the increasing bulk of data gathered by sensors and the data visualizations created by algorithms. The third topology is marked by a greater variety of sensors and the heterogeneity of networks to produce a “mass dataveillance” (Clarke, 2003), through aggregation of data from different sources: cookies in internet browsers, implantable RFID tags in documents, implantable chips to track individuals’ movement and exact location, medical data to map the spread of infectious disease among many others. All digital traces are gathered not only to describe real-time data activity in physical space (as described in the previous topology) but to creative predictive models based on identifiable communication patterns in the gathered data. In this topology, big data mining and data analytics are pushed to the limit of representation of current physical reality. Based on the accumulated data and identified trends, hybrid spaces are built to represent future plausible realities and to inform decision-making that will lead us to a reality we want to create.

The pervasiveness of digital media across all dimensions of life has shaped processes of knowledge-making accordingly to the epistemic actions of digital data. As overlapping topologies, data mining renders multi-scalar hybrid spaces and enacts an algorithmic form of knowledge of our biologies through data correlation. The transcoding of the analog world into binary information creates non-semantic metadata, which levels the play field between human and machine actions and allows for the collection and correlation of data. As subjects construct new objects of knowledge based on new strategies to generate, aggregate, and analyze data, this new knowable reality also speaks about the subjects that are immersed in it.

Chapter four examined how practices of self-making are devised through self-tracking. I examined how followers of the Quantified Self movement and participants in the “Truth or Dare” installation adopt quantified data as parameters to construct knowledge about their bodies and their sense of morality. I approached quantification as embedded into a wider context of rationalization of human practices and of scientific knowledge. The creation of instruments and technologies to objectively measure natural phenomena (Kuhn, 1961), for example, turn observable reality into categorized objects of science, in the administration of production of symbolic and material goods (Beniger, 1986), in overall, all aspects of lived experience (Foucault, 1978, 1984). The rationalization of practices is bound to the quantification of knowledge, also tied to a notion of progress and the definition of the role of technologies (as instruments of measurement) of constant enhancement of performance. Observable phenomenon is quantitatively specified, of what, qualitatively is already known (Kuhn, 1961, p. 179). Quantified data reproduces the rhetoric of mechanical objectivism of scientific discovery that argues that "good" science is one freed from human subjectivity, secured by rigorous and reproducible methods that are capable of accurately measuring phenomena despite of the agent conducting the experiment. Quantified data presents itself as a more efficient form to manage knowledge, as its numeric organization disguises its performative constitution. Ultimately, quantifiable measures aims to provide more accurate records and keep track of historical progressions accounts to measure scientific progress. Jennifer Slack and Gregory Wise (2005) alert that when technological devices are reduced to the role of measuring (as our quantitative "yardsticks"), we limit the construction of knowledge to what a "yardstick" can measure (i.e., height), and lose sight of the broader qualitative aspects of reality. "But finding an appropriate yardstick to measure progress is especially difficult given the qualitative nature of many goals of progress. How does one measure betterment? Happiness? Harmony? Spirituality? Morality?" (Slack & Wise, 2005, p.11). Because numeric information is tangible, easier to keep record of and administer, it becomes a more manageable parameter to measure progress. The main motivation of self-trackers in the Quantified Self movement is to build "self-knowledge through numbers," through continuous data collection of as many data sources as possible (heart rate, sleep cycles, calorie intake, etc.). The measurement of progress is closely tied to the quantified output provided by the sensors and applications. More technology and more ways to measure equal better ways to care for the self and, in exchange, might produce constantly improved, better selves. In this case, social progress and individual betterment are perceived as tied to a linear notion of technological progress. The consequence of these practices are the production of self-governed bodies, as individuals auto-tune their performance based on immediate feedback from sensors and apps, and the automation of decision-making based on algorithmic prediction; for example, when a participant takes the ToD insertion of #lie as a moral assessment of a tweet. Self-tracking practices can also lead to an obsessive attachment to quantification as an end it itself, and the operational complexity of self-tracking instruments might blur the strategies that operate them. When self-trackers trap themselves into the cycle of numeric validation provided by apps, they fail to acknowledge the political dimensions that operate the parameters for production of knowledge and truth.

Self-tracking practices can also be purposefully useful for health tracking, for example, as they incentivize more attentive self care, and might also stimulate a sense of awareness about the constitution of mediated subjectivities. Followers of the Quantified Self movement often conduct self-tracking practices in a speculative manner, not necessarily targeting at a specific goal. This open-ended approach sometimes can also prompt reflections about the act of tracking per se. In these cases, self-tracking is not limited to an obsession with efficiency. Even though the collection of personal data still aims for gain of leverage over how the body performs, it also relates to curiosity and exploration of the physiology.

During the ToD installation, participants were challenged to engage with digital data as a parameter for a regime of truth. Participants crafted their identities as liars or truth-tellers based on how they validate or challenge ToD's assessment. The making of the self in the situation of the ToD installation takes a moral tone and invited a discussion of how we relate to technology as an objective tool to evaluate truthfulness. Some of the interactions demonstrated that participants were intimidated by the possibility of ToD revealing undesired "truths." In this case, the interactions were focused on testing the functionality of the application through control statements. By tweeting statements they felt confident about their truthfulness (i.e., their own name or age), participants attempted to verify if the algorithmic assessment "worked" when the app output coincided with their own. This type of interaction establishes a premise that moral judgment can be automated through algorithmic analysis, and the testing occurs merely to assess if ToD has the technical capacity to fulfill this premise. Alternatively, for others, the role of ToD is not to confer intrinsic validity to true discourses, but to provoke self-reflection and examine the setup of strategies of construction of truth. When participants engaged with ToD in ways that extrapolate the notion of technology as tool, they acknowledge the dynamics of the installation as a game of truth.

In both situations of self-tracking practices—in the Quantified Self forum and during the ToD installation—practices of self-making are devised based on numeric parameters to construct knowledge and truth. Both practices are tied to a regime of production of truth that bases on transcoded physiological data, as a biological-computational assemblage, to produce parameters to care for the self's body and to build a moral compass.

While the previous chapters addressed implications of a digital episteme (Maddalena, 2014) to the construction of data topologies and of subjectification, chapter five dwelled with the political implications of such arrangements and how they articulate power dynamics. While personal data collection in the level of the individual produces accountability and self-governance, in a larger perspective, data mining and correlation is also dangerous because the pervasiveness of data collection challenges current parameters of individual privacy. To explain these dynamics, I analyzed the context of big data mining as a surveillant assemblage (Haggerty & Ericson, 2000) and as an enactment of Deleuze's (1997) conceptualization of a control society. In this sense, the surveillant assemblage acts as territorializing and de-territorializing machine, as data is massively collected from individuals as discrete units and later regrouped to form a composite profile of populations that assumes characteristics based on statistical relevance. One of the dangers of big data mining lies in the opaqueness of data mining processes and the asymmetric capacities to collect and process data that marks a big data divide (Andrejevic, 2014). Discussions in the Quantified Self forum demonstrated that self-trackers are increasingly aware of the implications of data sharing and the trade-off for making their personal data available. The concerns expressed also touch on possible misappropriation of databases for purposes they might not know nor have control of. In response to these dangers, self-trackers attempt strategies to protect themselves from potential data breaches and try to regain control over the process of data collection and processing by avoiding proprietary hardware/software and manipulating data in its native format. The DIY initiatives by self-trackers can be perceived as an action of re-empowerment, as they take over the reigns over all steps of data collection and correlation, but it can also be perceived as a naïve undertake, as their expectations of raw data might be associated with completely overcoming competing power relations. I perceive the DIY initiatives developed by self-trackers as forms of productive resistance in the form of rearrangement of distributive agency. The goal of the hacking resistance is not the liberation and the overcoming of power structures, but the constant rearticulation of the protocological power relations (Galloway, 2004).

Contributions and limitations

As anticipated in the introduction of this dissertation, this study established dialogues with digital media approaches to humanities and cultural studies. Within these areas of research, this dissertation presents historical, theoretical and methodological contributions.

Historical: I present a genealogical account of the Internet of Things that reconciles the roles of industry, academy and grassroots movements in its implementation. This dissertation provided a historical survey of the infrastructure of the IoT as established in terms of material and discursive formations that are biased towards forms of social organization, identity and exercise of power (Innis, 1951/2008). I presented the formation of the Internet of Things as emerging from institutional research in the industry, academic research in universities and grassroots movements in hackerlabs and makerspaces. In order to build a narrative that included a range of the competing and converging forces that contributed to the current state of the IoT, I conducted a survey of messages exchanged through the Xerox Parc list serv, examined the timeline of academic publications and the creation of research groups interested in the theme of pervasive and ubiquitous computing and investigated the intersections between the history of hackerlabs and the emergence of hackerspaces. Through this initiative, I built a unique report that traces the history of technological development, and also recuperates the roles of the different social forces that acted on the formation of these technologies.

I also acknowledged the role of the social imaginary of ubiquitous computing as a moving target that informs the vision of the future of technology, and drives the development of research in pervasive computing. Lastly, I accounted for the material shifts and alternative business models of open platforms that prompted the heterogeneity of platforms and protocols that marks the Internet of Things.

Theoretical: I expand the concept of hybrid spaces (de Souza e Silva, 2006) to acknowledge big data mining as the underlying logics that sustain the multiple spatial scales in the Internet of Things.

In chapter three, I acknowledged that the Internet of Things is built upon articulated spatial topologies of different scales, as forms of digital embodiment. The concept of hybrid spaces (de Souza e Silva, 2006) is developed in the context of scholarship about mobile media and approaches space-making through location-aware technologies in ways that interlay digital data and physical space. The concept of hybrid space revises the separation between the virtual informatics of cyberspace and the concrete physical world, and argues for an approach for spatial practices that are built upon co-constitutive practices of mobility, as social networks also migrate to the physical spaces when added with location aware features.

While the concept of hybrid space challenges the dichotomy between cyberspace and physical space, it also sets up new arrangements for the understanding of location, beyond geographic coordinates. Eric Gordon and Adriana de Souza e Silva (2011) discuss the emergence of net localities. Net localities are created in the contingent relationship between technological developments, networked social practices and our own desire to be locate and be located. "Now, what is being organized is not just information, but the physical world that contains it" (Gordon & de Souza e Silva 2011, p. 7). We no longer "enter the web" from a fixed locale; we exist within a continual hybrid space; "(…) physical space has become the context for […digital] information" sharing (Gordon & de Souza e Silva 2011, p. 9). The emergence of net localities is then illustrated in a history of strategies for mobile annotation of space and the development of LBSN (Location Based Social Networks) and LBMG (Location Based Mobile Games).

The effects of the pervasiveness of digital data have been demonstrated by how location-aware devices interact with physical spaces to produce hybrid spaces. This dissertation complements the previous analysis by de Souza e Silva and Gordon and contributes to the field of mobilities and mobile communication by calling attention to the affective dimensions of the pervasiveness of digital data in terms of its epistemic action. I push the discussion of spatial practices further and examine the topologies of hybrid spaces as constituted through heterogeneous arrangements of technologies as articulated folds (Deleuze, 1991) of digital data.

My approach to the appropriation of pervasive computing technologies problematized the construction of knowledge through the material and spatial arrangements of data and its epistemic action. I describe spatial topologies as built upon data gathering, data analytics, and visualizations that are enacted by users and technologies, from active/intentional data collection to sentient big data mining. In the self-tracking practices that took place during the ToD installation and as described in the accounts of the Quantified Self forum, the interactions with users produced multiple folds of transcoded data: in the physicality of the body unfolding on physiological data, correlated data that flows to data lakes, lines of code and programming as composition and a body of knowledge, code writing as exercises of control for human and non-human agency. The interactions between users and data implies in a co-constitutive motion that animates the becoming of spatial forms as abstract bodies of knowledge, when the user creates a data double of herself. The interactions between users and data also produce tangible bodies of matter, when a self-tracker applies knowledge learned through self-tracking to intervene on her physiology and improve upon her health condition. The epistemic implications of the material organization of digital data are in the affective dimensions that simultaneously render how we construct knowledge about ourselves and the world we inhabit.

Theoretical: I apply a framework of a digital episteme (Maddalena, 2014) to discuss practices of self-tracking and self-governance. Throughout this dissertation I discussed the interrelationship between the analog/physical world and the digital in ways that characterize it as a creative and co-constitutive rendering, in ways that do not reduce the digital materiality as a binary decryption of unintelligible, "natural" phenomena. I adopted an interdisciplinary approach that intertwines embodied physical computing (through the auto ethnographies and ToD), with digital media theories, and cultural studies, that privilege the performative action of data as founded upon a numeric, discrete and modular strategy of knowledge construction, as well as a material enactment of power. While scholarship that subscribe to a "new materialist" approach has attempted to reconcile the contribution of Foucauldian and Deleuzian scholarships (see Thacker, 2004; Galloway, 2004; Galloway & Thacker, 2007), this dissertation furthers this articulation and opens a new avenue of inquiry through the analysis of self-tracking through pervasive computing technologies as a practice of self-making and as a strategy for self-governance.

During this dissertation (and more intensely on chapter four), I articulated self-making through the performative action of constructing knowledge about the self through self-tracking, while herself is embedded into the collective sociotechnical assemblages of enunciation, in which the self is simultaneously a product and the producer of the assemblage she is part of. The acknowledgement of this autopoietic dynamics that characterizes the becoming-knowledge, becoming-selves, and becoming-world reconciles a separation between objectification and subjectification, and of technology appropriation as a measuring tool to a material arrangement through which forms of knowledge are enacted.

Digital processes articulate specific political-cultural sociotechnical practices that require conceptualizations to be redefined. As reminded by Beer and Gane (2008), concepts and frameworks function as rhetorical devices within different approaches to the study of new media. By looking at how concepts and frameworks were set up in media history, I paid attention to how these concepts and modes of thinking are shaped within and of the material forms and processes they try to comprehend. For this reason, I reinforced the term self-making in this discussion and often apply it in substitution of subjectification because of the positive connotation that it carries, as an active and productive endeavor; while subjectification is often presented with its twin, objectification, and connotes imposition and restriction. By enforcing the creative aspect of self-making I do not fall into the Enlightenment model of a rationalist and autonomous conscience that is in charge of its cognitive process. Instead, I approach self-making as an arrangement of distributive agency, that operates through the rational intellect, but also through the non-linguistic sensorial capacities of the subject. I apply this perspective to the construction of a sense of who we are ad how we produce ourselves through technologies, but also how we (re)produce the world around us and embody space.

Theoretical: I describe data as performative and as a rhetorical device: I alert that one danger of big data mining lies in the power of its epistemic action. Algorithmic analysis intensifies the rhetoric of data as objective and neutral and produces assumptions that correlated data patterns are factual truths. Big data mining privileges correlation and prediction over explanation and comprehension. For this reason, correlated data can identify *what* is happening in the data set, however, the nature of statistical correlations does not demonstrate contextual information that explains *why* they are happening. Issues of social profiling and discrimination arise when data analytics is taken as face value to determine relational dependency in a complex social context. It is because of this lack of explanatory power that I argued that statistical analysis cannot be the sole approach to understand the dynamics of data mining (as Chris Anderson argues in his 2008 article on the "end of theory"). The call for raw data, while valid in terms of how it provides greater flexibility for data correlation, cannot be setup as a wild goose chase for objectivity. In this dissertation, I acknowledge this contextual shortcoming of data analytics when I reaffirm that social research must acknowledge and approach data mining in the broader context of the knowledge-power apparatus it emerges from. For this reason, I argued that data analytics must be approached as a rhetorical device, in ways that acknowledge its bias and do not advocate for a pretense neutrality of algorithmic correlation.

Methodological: I adopt critical making as an experimental method for Humanities and Social Sciences research and as a gesture towards multimodal scholarship. The practices of self-tracking, pervasive computing technologies and the Internet of Things investigated in this dissertation, are emerging sociotechnical practices that, due to their novelty, require innovative approaches to their study. The requirement for innovation in research is present in the need to develop specific vocabulary to explain these phenomena in ways that are faithful to their digital complexity. Differently from a traditional instrument of data collection, ToD performs as an additional layer to the conversation, as a different modality of composition that engages in dialogue with the theoretical and analytical components of the research.

In the introduction of this dissertation and in chapters one and two, I introduced critical making as a research method and highlighted the potential contributions of critical making for research in the fields of Humanities and Social Sciences. Critical making recovers the pretense separation between abstract, linguistic based, individual thinking and proposes tacit, collaborative, hands-on manipulation of technologies to demonstrate that productive critical reflection is attained through material experiments. Matt Ratto (2012) emphasizes that critical making is more focused on "critique and expression rather than technological sophistication and function" and argues that the goals of making are in the processual "shared acts of making" and "practice-based engagement" rather than the evocative object (p. 253). ToD invites us to rethink empirical approaches to Humanities and Social Sciences by problematizing technology experimentation as one that "manifests as a source of uncertainty, bottom-up creativity and emergence" (Szerszynski et. al, In Büscher et al, 2011, p. 121). ToD is not a quest for technological mastery, but part of a critical making gesture that is a

> (…) moral, multi-sensory and collective strategy of taking fine-grained responsibility for innovation, placing researchers, designers and practitioners into the flow where technological innovations meet social practices, allowing them to experience, evaluate and react to the myriad frictions, troubles and opportunities that arise (Büscher, Urry, Witchger, 2011, p. 122)

The experience of constructing the ToD installation, the setup of two exhibits and the engagement with participants served as the material and technological lenses through which I approached the broader issues of self-making and the digital episteme, and specifically the practices in the Quantified Self movement. The ToD experiment allowed me to test the boundaries of theoretical concepts in media technologies. One of these situations, for example, explored the co-constitutive relationship between the (hard) physical and (soft) computing layers of galvanic skin sensors. My experience with physical computing components demonstrated that the assumption that hardware is stable and immutable while software is flexible is quite deceiving. I described in chapter two how the erratic readings provided by the analog sensors did not produce an immediate interpretation of the emotional state of the individual. Instead, the chaotic flow of numbers prompted a series of questions about the parameters of the code, about the physical contact between the skin and metal, about the transcoding process between electric current and the numeric logics of digital conversion. The first step of the critical experiment, in fact, initiated a series of theoretical and pragmatic questions that prompted me to reposition initial hypothesis and explore possibilities that I had not initially anticipated. While building the sensors and writing the code to process the analog input, I interacted with the practice of making in different levels of procedural literacy that challenged the separation between the hard and soft layers of the installation.

Procedural literacy is a specific mode of media literacy that entails the ability to apprehend, reconfigure rules of computing systems to solve problems. According to Ian Bogost (2005), code writing is one skill of procedural literacy, but it is not limited to it, "(…) any activity that encourages active experimentation with basic building blocks in new combinations contributes to procedural literacy" (p. 36). Procedural literacy is achieved through the ability to engage with procedural representation but mostly through the understanding of the interplay between the culturally-embedded practices of meaning-making and technically-mediated processes. As Michael Mateas puts it, "(…) the craft skill of programming is a fundamental component of procedural literacy, though it is not the details of any particular programming language that matters, but rather the more general tropes and structures that cut across all languages" (Mateas, 2007, p. 80). In the movement between play, experimentation and interpretation, important analytical skills are developed to analyze and construct sociotechnical mediations and a potential for critical awareness about these processes also arises.

The ToD experiment created opportunities for the analysis of the techno-social assemblage that brings to light how digital divide and asymmetric procedural literacy skills enact the potential for self-governance. In the situation of the ToD, the governance of truth is an ironic expression with very little consequences, but in social profiling applications of big data analytics, the parameters of governance might incur in discriminatory acts. Through the realization of this experiment, this dissertation provides evidence of the validity of critical making methods as an approach that is reflexive and informative about the social role of technologies. It is also a research method that fosters innovation in its inception, as the process of collective making often presents possibilities to open new avenues of articulations for how we relate to technology as a form of knowledge.

Limitations of the study

Even though this dissertation strived to present an account of the implementation of the Internet of Things that is inclusive of the different actors that contribute to the current architecture of the internet, the account presented on chapter one is biased towards a northern and mostly western perspective. The articulation between the research agenda of ubiquitous and pervasive computing at IBM and Xerox PARC, the material shifts brought by the development of smaller and faster computing components, and the articulation with hackers and makers presents a story of the Internet of Things that is American-centered. I argue that the account presented is representative of the creation of the Internet of Things, given that the term itself is northern by origin (IoT was coined by Kevin Ashton, U.K. researcher at the MIT when he initiated discussions on the potential of RFID for integrated connectivity among things). Another limitation of this study relates to the North-American, western bias that is also present in the observation of the Quantified Self movement.

Figure 23: Map of distribution of meet up opportunities for Quantified Self followers in the world.

The figure above shows a world map that pinpoints the meet up locations for followers of the Quantified Self movement. As the map demonstrates, the majority of followers is concentrated on the northern-western hemisphere. Sarah Watson conducted an ethnography of the Quantified Self movement in 2013 and affirms that even though the meet ups attract diverse demographics interested in self-improvement, mindfulness, and health care, the majority of attendees and of followers of QS in general skew towards white, male, silicon-valley-type [sic] developers or entrepreneurs. At the same time that these limitations in terms of geolocation, gender and race demonstrate how the Internet of Things operates through a biased perspective, they also trigger the need to conduct further research on alternative social-technical arrangements of the internet. I perceive it as a call to investigate how pervasive computing technologies and the embedded connectivity in the bodies of things and people are appropriated in different parts of the world where infrastructure and culture render different architectures of information. Paul Dourish and Genevieve Bell (2011) present a brief account of ubiquitous computing models implemented in South Korea and Singapore. They describe Singapore as a smart grid that integrates smartphones, and networked sensors for home surveillance, weather prediction and automated toll payment. Meanwhile, South Korea's ubiquitous computing infrastructure is massively funded by the public sector, which makes broadband internet available at low cost. The subsidy of internet connectivity by the government furthers the automation of domestic and public spaces in Korea. Even though Dourish and Bell (2011) present an account of ubiquitous and pervasive computing models in Eastern countries, South Korea and Singapore are countries which technological infrastructures are mature and developed. When compared to the U.S., they might even be more advanced, given that they were one of the pioneers in the implementation of mobile internet, and the small size of their territories presents itself as an advantage for the installation of infrastructure. Therefore, there a need for further investigations on the implementation and appropriation of networked sensors and other pervasive computing technologies in cultural realities that are diverse; in developing countries, with different political systems, and in non-urban areas.

Scholarship in the field of mobile media has analyzed how mobile technologies are appropriated accordingly to specific infrastructures and cultural practices in the world. Gerard Goggin (2006, 2011) analyses how different infrastructures of telecommunication (from 1G to 4G) interrelate to specific forms of cultural appropriation of cellphones and smartphones; Tom Farley (2005) compares the uses of mobile technologies, differences in regulation and policy and the effects in the implementation of wireless services in Europe, Japan and in the U.S.; Scott Campbell (2007) explores the cultural similarities and differences in uses of mobile technologies by teenagers in the U.S., Japan Sweden and Taiwan; James, & Versteeg (2007) challenge the impact of mobile technologies as agents to diminish the digital divide in Africa; and Adriana de Souza e Silva et. al (2011) discuss the makeshift appropriation of cellphones in favelas in Rio de Janeiro, Brazil. This scholarship demonstrates how the heterogeneity of communication infrastructures across the world, the diversity of technological protocols and regulation of access (i.e., China's firewall), and specific cultural practices produce diverse forms of appropriation of mobile technologies. This scholarship also serves as an indication and as a speculative gesture of what can be found in terms of appropriations of sensors, wearables and other pervasive computing technologies that shape the Internet of Things in different parts of the world.

Future studies

Future studies should extend the initial questions presented in this dissertation and explore the cultural specificities of appropriation of pervasive technologies (as mentioned as a limitation of the current study), investigate further practices of "digital redlining" (as mentioned in the introduction and explained in chapter five), and experiment with forms of data visualization that dismantle the mechanisms of data mining, through critical making experiments and other forms of digital activism.

In chapters three and five I argued that the pervasiveness of digital technologies has contributed to a naturalization of data as an objective measure of reality. The fine-grain resolution of data added with the inductive correlations brought by big data analysis confer an aura of "objective truth," capable of assessing reality effectively through mass data aggregation and correlation. In consequence, big data analysis often conflates data aggregation with knowledge construction. In chapter five I discussed the dangers of data analytics, specifically when it is applied in social profiling because it can reproduce and reinforce ongoing social biases. As a researcher from a Humanities and Social Sciences background, I advocate that these areas of expertise can provide valid contributions to practices in big data mining. I believe that the qualitative methodology tradition is complementary to provide the necessary contextual perspective to big data.

Given the growing interest in big data mining, the growth of the wearable market and the popularity of self-tracking practices, I expect that the number of studies that discuss these issues will increase. With this in mind, I believe it is paramount that studies focus on practices of "digital redlining" and call attention to the ways in which algorithmic analysis are appropriated by decision-makers for policy creation and regulation. The importance of this research is also justified by the need to update current legislation in civil rights and consumer protection in relation to newer strategies of access to information and services and develop plans to ensure that previous acquired rights are maintained.

Digital activism and media arts are productive approaches to investigate the mechanisms of big data because a subversive take on technological use evinces the power relations they are rendering. Future critical making experiments should follow the trajectory of media arts in ways that privilege the relationship between digital and biological embodiments as transitory processes more than stable states. Scholarship in performance and media arts also demands that we push the boundaries of research in media technologies even further.

Therefore, I believe that future efforts should be invested in making the mechanisms of algorithmic knowledge visible to users in order to demonstrate their dynamic constitution similarly to other forms of discourse. This move would allow us to engage with self-tracking practices as a productive and informative event about the self, instead of a defining standard to be followed. It would also prompt awareness about the underlying mechanisms that construct data analytics. In this sense, I also advocate for research in Humanities and Social Sciences to include aesthetic inquiries and a feminist approach to technology production as a fruitful territory of investigation.

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