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Animal Research, Self-tracking
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Autonomous Trap 001 (2017) by James Bridle

Autonomous Trap 001 is a trapping ritual for self-driving cars designed to raise questions about autonomous vehicles. The "trap" consists of a salt circle, a traditional form of protection – from within or without – in magical practice. By reproducing a "No Entry" road marking, the circle confuses the car's vision system into believing it is surrounded by no entry points, and entraps it.

The car itself is a research vehicle built by the artist, who wrote the software, equipped the vehicle with cameras and built neural networks to transform it into a self-driving car.

The project is part of Bridle's work and research on contemporary technologies of automation. It directs our attention to socio-technical issues such as the automatization of labour and the power asymmetries it creates, by allowing the imagining of a future where cab drivers chalk white lines on side streets to derail self-driving Ubers which are putting them out of work. In this respect, *Autonomous Trap 001* might represent a new possible form of socio-technical resistance.

James Bridle is a writer and artist working across technologies and disciplines. His work can be found at http://jamesbridle.com.

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Cover *Autonomous Trap 001* (2017) by James Bridle

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Training to Translate: Understanding and Informing Translational Animal Research in Pre-Clinical Pharmacology

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Abstract: We investigate translation in biomedicine by exploring how researchers supported by the British Pharmacological Society's Integrative Pharmacology Fund (IPF) have responded to increasing translational aspirations within pre-clinical animal research. The IPF sought to enhance institutional capacities, collaborative practices, and personal skills within in vivo research in the quintessentially translational fields of pharmacology, physiology and toxicology. We identify three manifestations of the influence of translational aspirations: 1) shifting from the standardisation of animal models to the alignment of research on animals with human therapeutic pathways; 2) expanding relationalities of care in animal research from a focus on the animal body to institutional arrangements around clinical care; and 3) changing training around research ethics, integrity and good statistical practice. Concluding, we discuss the value of working interactively with those involved in the changing practices of animal research and translation as a means to foster reflexivity about what matters when 'training to translate'.

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1. Introduction

This paper reflects on the changing research practices of in vivo pharmacology through the lens of co-produced research carried out with the laboratory animal community. In 2016, the British Pharmacological Society (BPS) funded us to conduct an evaluation of the impact and

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achievements of the Integrative Pharmacology Fund (IPF), a programme that aimed to support animal research and training in pharmacology, physiology, and toxicology in the UK. This involved carrying out interviews with laboratory animal researchers, but also collaborating with BPS members towards developing a framework for understanding the role of in vivo skills and relevant training in the future of pharmacology and related research areas. In what follows, we report our experiences in this project, with the aim of using them as an empirical ground to identify ways in which translational discourse may affect pre-clinical practices of animal research. At the same time, we reflect on how the changing understanding of animal research and translation in Science and Technology Studies (STS) can contribute to the development of laboratory practices within in vivo pharmacology.

Intellectually, this study is located at the intersection of three evolving literatures in STS. The first is work on the practices of laboratory animal research, which since Lynch's classic 1988 study has examined the material transformations and ethical implications of turning animal bodies into scientific data (Lynch 1988). The second is literature on the changing dynamics of translational research. Since the early 2000s, this has challenged linear models of translation, and instead charted the complexities involved in the movement of biomedical research into clinical practice (Sunder Rajan and Leonelli 2013). The third is the growing literature on engagement in STS, which is increasingly exploring when and whether STS should intervene (Martin 2016) and the role of STS in ethics and education (Joyce et al. 2018). What these literatures have in common is an interest in how 'good' science is understood and practiced. Animal research always involves scientific and moral uncertainties, as researchers and regulators work out "the proper relations between the suffering of the research animal and the health of the human" (Dam and Svendsen 2018, 349). The growth of translational imperatives in biomedical research (Harrington and Hauskeller 2014) is reshaping how these relations are understood, adding moral dimensions to the wider collaborations around animal research. These collaborations increasingly include social science scholars (Davies et al. 2016), who are working with the laboratory animal community to understand the practices of laboratory animal science and further both animal welfare and human health. The mutual entwining of scientific and ethical practices in the generation of what Thompson (2013) calls "good science" increasingly features reflexive social science as well.

In this paper, we exemplify these shifts – and the role played by translational imperatives within them – by drawing on our experience in working with laboratory researchers and BPS officers towards the development of discussions around good practice within in vivo research. We start by exploring the existing STS literatures on animal research and translation, drawing out the implications of a growing translational imperative in animal research for the organisational arrangements of animal

research, the roles and relations that are valued, and the changing priorities around reproducibility and validity. We then introduce our collaborative work and reflect on the potential for developing an STS-informed intervention in the practices of translational animal research in pre-clinical pharmacology, detailing the methods used to evaluate and analyse the outcomes of the IPF. On the basis of our sustained interactions with biomedical researchers, we then identify three ways in which the growing translational aspirations have changed pre-clinical animal research practices. Each of these shifts provides a space for productive engagement by STS researchers. They are: 1) shifting from standardising animal models to aligning research on animals with human therapeutic pathways; 2) expanding relationalities of care in animal research from a focus on the animal body to institutional arrangements around clinical care; and 3) the changing focus of training around research ethics and integrity, including different interpretations of statistical good practice. Concluding, we discuss the value of working interactively with those involved in the changing practices of animal research and translation as a means to foster reflexivity about the relations and practices that matter when 'training to translate'.

2. Re-evaluating Animal Research in Translational Pharmacology

Since Lynch's (1988) seminal work on how animals in the laboratory are transformed from naturalistic beings into scientific data, there has been considerable interest in STS concerning the complex practices of laboratory animal research. Ethnographic research inspired by and drawing on Lynch's study has tended to focus on three different dimensions to the work of transforming animals into data, which contribute to what research participants consider 'good' animal research. These can be characterised as: standardisation, care, and training. These dimensions are worth recalling here, for they still describe critically important aspects of the relations between animals, roles, and results that are choreographed in the production of meaningful data from animal research; and they also help to pinpoint how these imperatives have changes over the last thirty years. The organisational arrangements, allocated roles, and nature of affective relations with animals in the laboratory have all shifted slightly with the growth of translational practices in biomedical research. Under UK law, all animal research must be licensed by the Home Office (Animals (Scientific Procedures) Act 1986). Only projects with a positive harm-benefit analysis are authorised and all research must seek ways to replace animals in their research, reduce the number of animals used, and refine methods to reduce suffering and pain – that is, to apply the 3Rs approach of replacement, reduction and refinement (Russell and Burch 1959). The growth of translational research imperatives is now increasing the atten-

tion given to realising research benefits as both a scientific and ethical issue (Davies 2018) and altering the ways by which the 3Rs are applied. This is starting to change the way that standardisation, care, and training are understood and practiced.

The first dimension that has characterised the study of laboratory animal research in STS are the practices of standardisation in the production of 'good' laboratory animals. Historical studies on the development of animal research throughout the twentieth century and contemporary ethnographies of practices in animal research often stress standardisation as the route to reliable animal research[1]. Lynch noted that researchers designated particular laboratory animals as 'good' or 'bad', observing that "[t]he 'goodness' of the animal referred to the readability, clarity, congruence with anticipations of what the data should look like, and the ease with which it could be treated as a standardized member of a cohort" (Lynch 1988, 271). Standardisation remains an important consideration in animal research, but the scientific literature is increasingly concerned with questions around the standardisation fallacy (Würbel 2000) or how certain forms of standardisation intensify issues around validity (Richter et al. 2010). STS accounts increasingly talk about how translation is achieved through "balancing standardisation and individual treatments" (Dam and Svendsen 2018, 349). The unstable experimental humanised mouse model generates value as it becomes a "collaborative thing" around which new translational conversations can accrue (Davies 2012).

The second dimension, evident in Lynch's work and advanced subsequently, has been the STS attention to how animal research is co-dependent on the provision of 'good' animal care (Lynch 1988, Holmberg 2011, Bischur 2011, Viteritti 2013). Care is understood as a bodily and affective skill that underpins the validity of the data by reducing animal stress and ensuring that animals perform in the requisite and desired way. However, for much of the last thirty years, discussion of the role of animal care has been premised on a division of labour between care practices and research practices. Responsibility for care has normally been practiced by animal technicians who work in the animal research facility, and who provide specialised care for laboratory animals and support for the work of principal investigators. There were inevitable tensions between these roles, but as Birke and colleagues (2007, 117) suggest, "animal technicians and high-ranking scientists […] are bonded by shared understandings of what counts as 'good' animal care". Animal care remains critically important, but its scope is expanding in the context of translational research and changing regulation. Researchers, as well as animal technicians, are having to attend more carefully to animal experience to facilitate translation (Friese 2013). There is a growing attention by regulators of animal research to the "culture of care" of an organisation, which is concerned with how communication between roles happens within institutions, as well as the extent to which wider societal expectations of humane animal care are reflected in practice (Davies et al. 2018).

The third aspect of work on animal research in STS has been a focus on what it means to train people to work well with laboratory animals. Despret's (2004) work has been inspirational in drawing attention to how training generates the expectations and affects that authorises a good experimental performance and what it means to become an experimentalist (Holmberg 2008). Despret recounts the work of Rosenthal (1966), who used students enrolled in a laboratory course in experimental psychology to explore how their expectations of what kind of rat they were working with shaped the rat's performance in the maze. Despret explores how "the expectations of a good experimenter have authorized the rat to become competent" (2004, 120), whilst also noting how the rat authorises the student to become competent. Despret's work has informed subsequent studies of how becoming a good experimenter involves learning to "become with" animals. Yet, this too is changing as the expectations of 'good' experimental outcomes shift from the performance of the animal in the apparatus to clinical outcomes. Learning with animals remains a vital component of translational research practices. Friese has observed how training for translational research involved developing the "right 'touch' for surgery" (Friese 2013, 133), so that the researcher could now move between the parts and the whole of the mouse appropriately. The movements required for translation are now more complex: animals may have to be made, unmade, and remade as complex circuits of translation seek to match the performance of the animal to the human experience or mechanism it seeks to model (Svendsen and Koch 2013; Nelson 2018). This happens within experimental practices, but also through increasing contestations over the design of experiments and their statistical inferences (Würbel 2017).

As suggested above, these questions around standards, care and training are not only dominant strands in the STS literature on animal research, but are also growing discussions in the scientific literature. These discussions are particularly evident in the literatures around translational research and in pharmacology in particular. Pharmacology is quintessentially translational in its objectives and practices, as it explicitly seeks to bridge the gap between biological knowledge and drug development for humans and non-human animals. Yet this purported translational achievement is increasingly questioned. Discussions of the pharmaceutical 'pipeline' are frequently couched in terms of a crisis (Sunder Rajan 2017; Murphy 2017), referring to the failure of potentially promising new drugs to progress through the different stages of drug discovery and development from pre-clinical laboratory research (whether in vivo, in vitro or in silico), through safety and efficacy testing in animals and humans, to clinical trials in human patients. To date, this process of attrition has been most visible when drugs have failed to show efficacy in human clinical trials, for this is where 'failures' are most public and costly (Freedman, Cockburn and Simcoe 2015).

At the same time, there is a growing sense that these problems may also be identified and addressed through re-evaluating the practices of pre-clinical animal research. While in vivo research has long been positioned as vital to translational research, detailed discussion of the specific value and limitations of animal models in furthering clinical advances is more recent (for example, Collins 2011). Managing failures sooner in the drug discovery process may be less expensive and have ethical gains in terms of more effective human clinical trials and less animal wastage (Ioannidis et al. 2014). Growing debate over the reproducibility of many studies using animals in research (Academy of Medical Sciences 2015) and the failure of drugs tested on animals that subsequently enter human trials is further seen by some as a fundamental challenge to the ethical justification of biomedical research in animals (Pound and Bracken 2014). Researchers and learned societies are thus increasingly reviewing the different phases of in vivo research to look closely and critically at the practices for translating knowledge of disease mechanisms and treatment between species, including around validity of animal models, experimental design, reporting conventions and forms of animal husbandry and care (Begley and Ellis 2012; Concordat on Openness on Animal Research in the UK; Davies et al. 2017; Nuffield Council on Bioethics 2005; Osherovitch 2011). This raises questions about the operation of animal models, and also about the organisation and implementation of institutional models of translational research.

The opening up of discussions around animals used as models within the research community offers an opportunity to integrate STS studies of animal research with STS work on translation. Earlier models of translation, which viewed the process of producing tangible outcomes from scientific research in terms of a path – bench to bedside – strewn with obstacles to be overcome (e.g. Pober, Neuhauser and Pober 2001), have now largely been superseded. Many scientists and funders acknowledge the complex trajectories involved in translation and the challenges of fostering collaborative relations required to sustain interactive research (Collins 2011; Collins and Tabak 2014; Moher et al. 2016; Zerhouni 2003). Within STS, translation has increasingly been tracked and reinterpreted through attending to how knowledge moves: developing laboratory research with therapeutic outcomes relevant to humans requires organising and managing translational processes so that "biomedical claims, objects and practices" can "move across boundaries" between institutions, disciplines, and species (Sunder Rajan and Leonelli 2013, 466). This promotes certain forms of collaboration, standardisation and regulation. Furthermore, these movements are not only one-way. The movement between research, safety and efficacy testing and clinical trials is increasingly understood as non-linear and recursive, constituting what Lewis and colleagues (2014) characterise as "circuits of translation", which involve both material flows and conceptual transformations at each iteration (see also Crabu 2016 and 2018).

There is a significant body of work within STS focusing on patterns of translational research in genomics (Maienschein et al. 2008), meta-genomics (Levin 2014), stem cell research (Maienschein et al. 2008; Martin, Brown and Kraft 2008; Fagan 2013), neuroscience (Brosnan and Michael 2014) and plant science (Leonelli 2013). The complexity of translation they indicate can help in developing new ways of thinking about the role that animals play in translational research and the training required for researchers to facilitate these practices. Standardisation is no longer the overriding imperative in animal research. Translational animal models need to be stable enough to move, but also sufficiently adaptable to be able to encompass the changing understandings of disease that happen through circuits of translation (Davies 2012; Dam and Svendsen 2018; Nelson 2018). Care for the animal is increasingly seen as not only a shared ethical value, but also an essential component of research, when translation is dependent on stress-linked immunological and other responses (Friese 2013; see also Seok et al. 2013). Training has to be opened up to multiply the "the body we care for" (Despret 2004), to include attuning to and transforming humans as well as animals. In translational research "scientists calibrate animals against the medical phenomena which they are intended to represent. In turn, human medical conditions and the patients who manifest them have to be calibrated against the rodent models" (Lewis et al. 2013, 776).

The question for this study is how far the changing understanding of animal research and translation in STS can contribute to shaping these practices in productive ways. In the next section, we discuss the methods and context for research that we carried out in collaboration with the British Pharmacological Society (BPS) as part of their processes for evaluating past funding and developing future training for pre-clinical animal research.

3. Evaluating the Integrative Pharmacology Fund

This research emerged from a commission, by the BPS, for the authors to evaluate the outcomes of the Integrative Pharmacology Fund (IPF). The BPS are a membership charity, whose mission is to promote and advance pharmacology. They have played a role in the development of in vivo skills in the UK by driving long-term collaborative partnerships and providing funding. The BPS launched the IPF in 2004 as part of its efforts to address a perceived in vivo skills gap (ABPI 2005). It was run between 2004 and 2014 by a consortium involving the BPS and three major pharmaceutical companies: AstraZeneca, GlaxoSmithKline, and Pfizer (see Collis 2006, 2009; Lowe et al. 2016). The IPF was led by a steering group comprising representatives of the funders. It worked with national funding bodies (the Biotechnology and Biological Sciences Research

Council, BBSRC; the Medical Research Council, MRC; and the Higher
Education Funding Council for England, HEFCE) to support in vivo ed-
ucation and training. The initial £4 million investment in the IPF was
used to leverage total support of £22 million for in vivo research, educa-
tion, and training. The IPF thus constituted a significant focus for the
BPS for over 15 years; was a substantial investment of both public and
commercial funding; and has played an important role in shaping the
practices, skills and training that have defined pharmacology in the UK
over the last 15 years.

The authors were approached to provide an evaluation of the IPF be-
cause of past experience in working collaboratively with the laboratory
animal community (Davies et al. 2016). The overall scope and organisa-
tion of the evaluation project was co-produced between Davies, Lowe,
and Leonelli as independent researchers, Anna Zecharia and David Lewis
as representatives of the BPS, and BPS member Michael Collis as an in-
dependent consultant (following former leadership of the IPF). The pro-
ject was given ethical approval through the University of Exeter. Research
started with a review of the current literature on in vivo skills training
through academic and grey literature. Two questionnaires were delivered
to those who received IPF support as a Master's or PhD student (25 were
returned) and those who were appointed to fellowships or staff positions
as a result of IPF support (17 were returned). These were used to gather
basic information and recruit participants for semi-structured interviews.
Lowe conducted 19 interviews with 20 participants. All participants had
been, and many still were, engaged in work using in vivo research. They
were asked about how the BPS had supported their work and invited to
reflect on the changes they made to the design and conduct of experi-
ments through this training, including around ethical practice, public
outreach and research translation. The transcripts of these interviews
were coded using the qualitative data analysis software NVivo. The evalu-
ation was completed through two stakeholder meetings organised by the
BPS, which provided feedback on the initial findings and enabled the
whole evaluation team to develop recommendations in conversation with
key stakeholders.

The distinct roles of the University of Exeter researchers and BPS
representatives were negotiated at the start of the project to establish
boundaries that protected the independence of key aspects of the re-
search and the identity of research participants. A firewall was construct-
ed between the University of Exeter and the rest of the team, ensuring
only the University researchers had access to the full results of the ques-
tionnaires, including the identity of the respondents. Participants for the
qualitative research interviews were recruited from the lists provided by
the BPS and sampled by the authors to encompass a diversity of thematic
research areas, institutional positions, and personal experiences with the
IPF. Of the interviewees, for example: one was the head of an Integrative
Mammalian Biology centre (an IMB, discussed in section 4), eight were

researchers working as fellows or permanent research staff members at IMBs, four encountered the IPF as postgraduate students, three worked in senior technical positions at IMBs, two were recipients of 'pump priming awards', and a further two were well-established figures in animal research who were not based at IMBs. To enhance the integrity of the data collected, participants were promised full anonymity and only anonymised quotes from interview transcripts were shared with the BPS. It was agreed at the outset that the data generated in the project would be owned by the BPS but could be used by the authors in subsequent publications independent of the BPS.

The final evaluation report was jointly agreed. The main body of it detailed the empirical material generated, analysed and drafted by the University researchers. The introductory material and final recommendations in the report were guided by the requirements of the BPS, drawing on the interviews and workshops, and agreed in consultation with the BPS council. For the authors, this project constitutes a constructive engagement and intervention into science policy in an area for which the BPS assumes professional responsibility. It is notable that this 'serviceable STS' was for an organisation with little executive power itself (Webster, 2007), but with an established role in guiding norms and standards for its field. The outcomes of the study thus focus on how the organisation and practices of translational pharmacology can be enhanced through education, training, and reflexive conduct by practitioners. The intervention is shaped by the aims and activity of the BPS itself, but also the restricted and specific scope of the power and influence of that organisation within a wider context of education, skills, research and industrial policy and activity. The report was launched in December 2016. One of the initial outcomes from this work has been the development of an undergraduate core curriculum for pharmacology courses in the UK, which was launched in 2018 and now has over thirty organisations signed up[2].

This paper has been developed subsequently and separately from the commissioned work. The interview transcripts used for the evaluation were further analysed to explore how researchers manage the different accountabilities and changing aspirations in translational pharmacology, drawing on coded responses to questions around 'best practice', 'translation' and 'the 3Rs'. In the next section, we draw on this material to explore how translational aspirations are changing the practices of standardisation, care, and training indicated by earlier studies in STS. We show how the work of transforming animals into data sources is being recalibrated at an institutional level, changing what is valued as 'good' science from standardising animals to aligning experiments, expanding institutional interactivity, and in deliberations around balancing research design with the 3Rs.

4. Training to Translate: The Recalibration of Animal Research in UK Pharmacology

A key element of the IPF initiative was the establishment of four Integrative Mammalian Biology centres (IMBs) across six UK universities. These brought together the different disciplines involved in pharmacological research, and were involved in employing staff, awarding PhDs and establishing Master's degree courses to build future capacity for in vivo skills in pharmacology. The IMBs were intended to form centres of excellence, with responsibilities for promulgating high standards of animal welfare and developing innovative forms of research. An important aspect of this was advancing the translational potential of research. This involved a series of changes to practice that we identify below.

4.1 From Standardising Animals to Aligning Pre-Clinical and Clinical Experiments

Different forms of pre-clinical animal research use animal models in different ways. While standardised strains are still used for regulatory toxicity and safety testing, research into specific human diseases or injuries involves the use of 'bespoke' animal models created to model particular aspects of a disease[3]. This dual use of animal models leads to a diversity of proposed solutions to the problem of enhancing translation through in vivo research. Some commentators demand greater standardisation in research, for example through standardised reporting of animal research (Kilkenny et al. 2010), the reduction of bias in publications through experimental randomisation and blinding, the publishing of negative results (van der Worp et al. 2010), and the development of standards for recognising the importance of genetic background effects in animal models (Crusio et al. 2009). Others stress enhancing sensitivity to local experimental situations and individual disease trajectories, including incorporating animal care and environmental enrichment into translational research (Richter, Garner and Würbel 2009; Friese 2013), developing more personalised disease models (Davies 2012), or using biomarkers and so-called reverse translation methods to move in non-linear ways between animal models and individual disease trajectories (Garner 2014). These are not mutually-exclusive, since standardised reporting and greater experimental variability can work together, but these debates do indicate the tensions researchers face in striving for translation in their work.

In our interviews, researchers talked about how they had increasingly moved away from established 'gold standard' models in animal research, instead seeking to match experimental and clinical treatment regimes. This happens, for instance, when seeking to align in vivo research with clinical trial protocols, and model patient experiences alongside disease characteristics. In other words, there has been a sustained attempt to shift

research focus beyond the animal body and related forms of standardisation and control, and towards the circumstances and requirements of clinical care and related institutional arrangements.

Many researchers report making changes to experimental design, especially strategies around dosing techniques and levels, to enable them to scale up to human clinical studies. Some have suggested that there has been a recent shift away from using dose levels in animal research that would generate a statistically meaningful – and thus publishable – effect, towards asking whether the doses and methods of drug application could translate meaningfully to humans, as exemplified by the following quote:

> Are they using the animal model that they are working with in the correct way? Are they dosing at a dose that you could think of translating to a human equivalent that would be actually realistic? Are they thinking about what route of administration would you be giving it in humans in order to actually think about bio-distribution and those sort of things quite early on? (Senior researcher at a small university, 2016)

As pointed out by the same interviewee, sometimes addressing these questions means changing experimental protocols in animal research 'upstream', to match the likely downstream mode and dose of clinical application:

> I've become increasingly convinced that if you are going to do a drug IV [intravenously] then it's got to be IV in the mouse. […] And within the literature I work in, the [mouse model that the interviewee works on] is just littered with examples of mice being fed, or whatever, huge quantities of a drug of some sort which is completely unfeasible in man, completely unfeasible. That's very disappointing because what we've seen historically is clinical trials being developed on the basis of the mouse work, but a disconnect where the human receives a fraction of the scaled dose that the mouse got and it's not surprising that it's not a very successful trial. (Senior researcher at small university, 2016)

Further interviewees discussed how the design, validation, and use of animal models are themselves modified to produce results of greater translational potential. One researcher described a change in use of mice models to simulate the human experience of neurodegenerative disease, where drug treatment follows diagnosis rather than preceding the onset of symptoms:

> We wanted to use an animal model and a time course that was going to be translational. What a lot of previous work does is set up an animal model, of Alzheimer's or Parkinson's for example, but they'd pre-treat it with the drug before the model was initiated. So translating that to people is effectively like treating anyone over 50 with a drug in the hope that a few of them get Alzheimer's disease. They won't get Alzheimer's disease because you've given them the drug. So that was one of the prob-

lems in what we were doing. So we sort of worked quite hard to design a study so that you set-up the model, wait a certain period of time to make the animals how a person would be when they get to clinic with Parkinson's or Alzheimer's, for example, and then that's when you start the drug treatment. (Postdoctoral researcher at large research university, 2016)

Another researcher talked about moving from using adult rats to using elderly rats, and small focal lesions to larger ones, to better model important characteristics of people affected by stroke. As well as changing the experimental temporalities through matching older animals to older patients, they also changed the treatment period to match median hospital admissions and facilitate the organisation of later clinical trials:

In one of our experiments we were infusing the protein into the muscles of the animals for a month after stroke, starting 24 hours after stroke. He [the clinician] challenged me on it. And he said, that's really interesting, but why would you choose a month, because in practical terms it's really hard to run a clinical trial like that, as the majority of our patients discharged, the median stay is 13 days. […] So he said, you've got to find a way to compress this down into a timeframe that's compatible with our patients. (Mid-career researcher at a large research university with a neighbouring hospital, 2016)

This search for a more 'translatable' animal model is recognised to have trade-offs. The time involved in allowing disease aetiologies to develop may be expensive, and there may be welfare implications if animals with disease symptoms are used in procedures for longer periods (as, for instance, in the case of diet-induced obesity in mice). In addition, outcomes are still uncertain even using the 'best' available models. Some researchers explained how they were including aspects of patient experience in their pre-clinical studies. Examples involved modelling comorbidities in experimental stroke research by using hypertensive rats; and using analgesics on animal models, which better represents patient experiences while also promoting animal welfare.

The increasing interactivity fostered by aspirations for translational research is promoting the alignment of drugs, doses, models, and temporalities between pre-clinical research with clinical trials and clinical application. The interviews indicate growing acceptance that the evaluation of animal models requires revision to include their potential translational value (as argued by van der Worp et al. 2010 and Garner 2014, among others). The specifics of this vary by disease area, and researchers stress how improving translational in vivo research is complex and iterative, rather than a one-way linear process. Several interviewees described collaborations as vital for changing both the experimental design and pharmaceutical agent, so that a viable compound can be taken from the laboratory into a clinical trial or clinical setting:

A lot of the drugs I was using in my PhD were quite unstable. So I couldn't give them in drinking water or in their food, for example. I had to make up the drug fresh each day and give the animal an injection. In some of the work we're doing here, with the help of [the pharmaceutical company funding the laboratory] we've been able to mix the drug for example into the mouse food so that they can eat it without having an injection twice a week. (Postdoctoral researcher at a large research university, 2016)

Indeed, this trend towards context-specific alignments and equivalences increases the complexity of pre-clinical research data and may work against those who view standardisation as a solution to the translation gap (Lewis, Hughes and Atkinson 2014). This increasing complexity demands renewed attention to how care is practiced in translational research, both for animals and for people.

4.2   Caring for Animals; Caring for People

Pre-clinical pharmacologists sit at a critical juncture between basic and clinical research. In addition to the experimental realignments presented above, this also involves working in new organisational configurations and incorporating new relations of care for research subjects, whether they be humans or non-humans. Interviewees talked about needing to be more responsive to the multiple responsibilities involved in developing interdisciplinary research collaborations, thus reflecting on the new forms of accountability brought about by bringing laboratory and clinical practices closer together. As Crabu suggests, in translational research "the laboratory itself can be re-framed and adjusted to render laboratory facts and scientific phenomena congruent with the processes of care and the clinical management of patients" (Crabu 2016, 3). This changes where problems are defined, how they are framed, and how they might be addressed.

Throughout the interviews, participants highlighted their efforts to develop new relations between basic, pre-clinical and clinical researchers, so as to create the interactive and recursive mobilities between disciplines that facilitate translation. One interviewee used the terminology of 'back-translation' to identify this shift. This highlights the reversion of the stereotypically linear, bench-to-bedside direction of translational research, and acknowledges how researchers are now seeking to answer questions coming from clinical care in pre-clinical research. In their words:

In the past, mainly my research was based on research which was done on animal models and problems that people identified in more molecular problems. Now it's also directed by problems in the clinic. So […] I'm more thinking about how problems identified in the clinic can be back-translated and how animal models can help answer the question. (Early career researcher at a medical school, 2016)

Beyond answering questions generated across basic, pre-clinical, and clinical research contexts, the translational mobilities of in vivo research also require understanding how answers are given value and statistical significance within different experimental systems. Statistical measures of biological significance have tended to be domain-specific and to some extent incommensurable with each other. Given this context, informal dialogue between pre-clinical and clinical researchers aids further understanding of the criteria by which answers will be deemed to be biologically significant across other domains. Being involved in translational research means adopting statistical standards that will protect patients in clinical trials, which are not necessarily the same as those meeting the thresholds for publishing in basic research, as highlighted by the following interview quote:

> I am more aware of the clinical research and the types of designs for clinical trials, which maybe I wasn't aware of before. So it's widened my knowledge and my circle of reading and I am aware of the very stringent criteria there are for clinical trials which there isn't in basic science […] There's this fallacy that exists where people tend to think that an n of 6 is enough for a significant experiment in the animal world, whereas that's a ridiculous way of thinking now. The group on stroke, they are far further down this line than I am, so they have the pre-clinical stroke models and they work very closely with the clinicians, so they have much more dialogue. And so being involved with their lab meetings and in just general tearoom discussions, I've become more and more aware of how stringent we need to be when, first of all, designing experiments and then doing power calculations but also in interpreting our data as well and determining what is or what isn't biologically significant. (Senior lecturer at a large research university, 2016)

This exchange can also go the other way, with clinicians being trained in animal use and care. One interviewee, who was appointed within an IMB centre to help share expertise on animal research, talked about how they were able to introduce clinical researchers to the required skills to conduct animal research. Clinicians were guided through the process of initiating a project, matched up with potential collaborators, and given training to design and conduct experiments with them. In their words:

> In terms of marrying up clinicians to any in vivo research side, things have certainly progressed. Those individuals had never had any experience of working in an animal model, but [want to] in order to progress their work […]; essentially, they'll ask, 'I want to do some animal work. Who do I talk to?' Then they end up talking to me. (Research and technical support at a large research university, 2016)

Some collaboration focused around formal roles allocated via the IMB centres, such as the research management role above. Other forms of interactivity were brokered through jointly-supervised PhD studentships,

which were "always highly favoured where there were two supervisors for different faculties […] which could bring together basic and translational skills" (senior manager at a large research university, 2016). Other collaborations were more informal, facilitated by the co-location of IMB centres near large teaching hospitals. As one researcher suggested, informal meetings with a clinical researcher with everyday experience of patient care had provided advice that would not have been available from the literature, but which had affected how they designed and conducted their experiments:

> We probably meet once or twice a year on average, and he asks me what I've been doing, and I tell him what I've been doing, and he explains what the challenges are in translating this kind of thing. He's given me a couple of really good bits of advice which made me think about how to do the work that I do. It's these kinds of little gems of information that you can't get from the literature and from chatting with your friends. It needs to be someone that works with stroke patients every day that can tell you the realities of it. (Mid-career researcher at a large research university with a neighbouring teaching hospital, 2016)

These informal collaborations do not involve formal working relationships and typically they do not result in the clinician being involved in co-authoring publications. Nevertheless, our interactions with IPF researchers show that informal collaboration plays an important role in facilitating access to clinical knowledge that comes from day-to-day interactions with patients. Informal collaborations supplement the technical and experimental knowhow developed through circuits of translation, by helping to identify matters of care in both clinical settings and animal research.

4.3   Reporting, Reproducibility, and the 3Rs

In this final empirical section, we explore how translational expectations in animal research are increasingly intertwined with policy and training on research integrity, reproducibility, and applications of the 3Rs. Training to become a 'good experimenter' today means conforming to multiple expectations, whilst navigating a shifting methodological landscape in light of the so-called crisis in the reproducibility in biological research (Academy of Medical Sciences 2015). Researchers in pre-clinical academic settings are often working in environments where there are career pressures to "win a place in a select few journals" (Horton 2015, 1380). However, top-ranking journals have been criticised for poor reporting of animal research, with few articles containing information on randomisation, blinding, and sample size estimation (Macleod et al. 2015). Training students in pre-clinical pharmacology means teaching them to negotiate the pressures and policies around research integrity, research reproducibility, and the 3Rs. This sort of training rarely appears in the literature on animal research in STS but is an increasingly significant

part of becoming a good experimenter (Leonelli 2017). Producing 'good' results may not involve working directly with animals but will require making 'good' calculations to get sample sizes right, avoid bias, and be transparent about the relationship between hypotheses and data.

Debates over rigour and reproducibility are particularly acute in in vivo research, where underpowered experiments and p-hacking result in animals' lives being wasted (Ioannidis et al. 2014)[4]. Several initiatives are seeking to enhance the conduct of biomedical research through improving reporting in academic journals, ensuring rigorous grant review, and supporting institutional leadership (Begley and Ioannidis 2015). The ARRIVE guidelines refer to the reporting of animal research and are increasingly incorporated into journal submission processes (Kilkenny et al. 2010). The PREPARE guidelines are intended to be used prior to research taking place (Smith et al. 2018). The National Centre for the 3Rs (NC3Rs) is developing resources to help in vivo researchers in the UK meet legal requirements to replace, reduce, and refine the use of animals in their research. These attempts to standardise and harmonise the conduct of experiments and programmes of research mirror international efforts on care and welfare of laboratory animals (see Bayne et al. 2015). They also change the attunement between expectations, animals, and affects that go into training animal researchers (Despret 2004). These are now mediated through written guidelines, checklists, and protocols. These document what matters in communicating research quality and animal care, but they do not resolve tensions for researchers who have to work out how to articulate their research to meet these expectations.

Our interactions with IPF staff revealed widespread support for the 3Rs, accompanied by a recognition that overall efforts to reduce animal use in research should not be at the expense of the statistical power of each experiment. Many had been involved in both teaching and outreach activities that prompted them to think about relations between research translation and the 3Rs. One researcher had contributed to the development of the Experimental Design Assistant[5], an online tool developed by the NC3Rs to assist the design of experiments. Nevertheless, divergence in practice remains. In interviews, we found that researchers talking about the requirements for reporting, reproducibility and the 3Rs held different views on the most appropriate experimental design for translating in vivo research.

One researcher, who otherwise sought reduction in the use of animals in education, argued for increased sample size as a way to improve a study's statistical significance:

> If I decide that a study's worth doing, I do my sample size calculations. But then in most cases, for a four-month study I'm talking about where you have a significant investment in time and energy, we do as many animals as we can in that timeframe. So, we don't attempt to reduce the number of animals, because when we do our sample size calculations, we realise that for all the additional animals we put in we increase our abil-

ity to detect a benefit of a drug and you reduce the chances of getting a false positive by accident. So I don't actually try to minimise my animal use, I just decide which experiments are really worth doing well, and doing them properly. And the reason for that is I think a lot of the low-hanging fruit is gone now, there are no easy stroke therapies that are out there. They're all going to be most likely small effect sizes, modest effect sizes, so you just need to power your studies as fully as possible. (Mid-career researcher at a large research university, 2016)

Another researcher preferred instead to use smaller numbers of animals, thus shifting focus to the magnitude of experimental effects:

So if you do an experiment in an animal model with a human condition and you get a small change for the better, that shouldn't be used as a rationale for going into man. You need to see a big change. A big change at a rational dose. I do quite a lot of consulting now in the neuromuscular field and I'm seeing datasets where I tell the company on the basis of this, that drug is not going to be clinically effective because the change is too small, and yet I've seen these programmes go through to full clinical development. (Senior researcher at a small university, 2016)

Both of the above researchers are concerned with the potential value of their experiments for future drug development and with ensuring that their results are reproducible and useful. Their experimental design is guided by their understanding of how data deriving from the drug achieves translational value in their field. If only marginal effects are thought to be possible, then larger sample sizes are used. If larger experimental effects can be anticipated, then using smaller sample sizes constitutes better practice. Even for people working in similar fields, on similar organisms, there are different understandings of what constitute good statistical practices for interpreting results in translational research. The extent to which experimental practices are sensitive to the concrete translational goals depends not only on the biology, but also on the prior history of investigation and therapeutic development in the relevant area of research, and the historical constitution of that research itself. The expectations between researcher and animals that Despret (2004) identifies as vital to producing "good experiments" are supplemented by researchers' interpretations of the technical requirements of translation.

While the two approaches discussed above come from established investigators, there are important lessons here for training early-career researchers. Future efforts to improve experimental design and statistical power would benefit from a better understanding of how researchers interpret the overlapping imperatives around the 3Rs, reproducibility, and translation in their everyday research practices. Again, our research suggests that standardised prescriptions of good practice should be approached with caution. Checklists and standards need to be supplemented with explicit discussions among pre-clinical researchers about the as-

sumptions that they make in their experiments, as well as discussions between pre-clinical and clinical researchers to ensure the applicability of findings across domains. Innovation around translational practices from animal research will not be achieved through compliance with reporting policies alone, but also requires discussion around the validity and mobility of the data that results. Minimum standards in check-boxes at the point of submission of a journal article need to be augmented by opportunities to encourage dialogue and reflexivity around research practice. This is exemplified by the very exchanges between STS and animal researchers that characterised our collaboration with BPS, and the uptake of the recommendations produced through these interactions, as discussed below.

5. Discussion and Conclusion

Our research with representatives from the four IMB centres funded by the BPS suggests widespread identification with current translational research imperatives. It also indicates that translational research practices are multi-dimensional and, at times, contested. In this paper, we identified and discussed three kinds of ways in which researchers who use animals in pre-clinical research are responding to imperatives to make their work more translatable. These include moving from the standardisation of animals to the alignment of experiments, connecting practices of animal care and patient care, and reflexivity in the calculation of statistical power and the 3Rs. Collectively, these constitute different dimensions through which the researchers with whom we interacted conceived of striving towards translatable science. These supplement the ways in which STS scholars talk about animal research and translation. They can also be used to inform the future training of animal researchers. In closing, we briefly discuss the practical implications of these findings for the improvement of in vivo research, and reflect on how, through sustained dialogue and reciprocal learning across STS and animal researchers, co-produced qualitative research can contribute to a productive reframing of how scientific practice is enacted, understood and evaluated.

Applying insights from STS scholarship within the initial evaluation of the IPF helped us to contribute concrete recommendations for the BPS. Many of these recommendations relate to the increasing complexities found in "circuits of translation" charted above, and sought to avoid being prescriptive, focusing instead on ways of enhancing reflexivity and learning across organisations and for individuals. The final evaluation report included key recommendations for supporting and assessing in vivo education, strengthening networks for sharing good practice, recognising the diversity of activities and careers involved in translational biomedical research, and enhancing collaboration between them (Lowe et al. 2016). It also details practical examples, including the emergence of new roles

for managing and facilitating the increasingly complex modes of dialogue and collaboration required for translational research.

The evaluation report also identified some specific challenges and opportunities for change. Some of the challenges relate to how translational research is changing career structures for scientists. There are potential barriers in the credit structures in science which value publication within discipline-specific journals. The researchers interviewed here do not exhibit strong disciplinary affiliations; they conduct problem-focused research, and some were members of more than one learned society. Work tracing the pathways taken by translational research indicate that these results are rarely in the highest impact factor journals (Cambrosio et al. 2006). However, regimes of scientific credit are evolving to accommodate new forms of publication and patent applications (see Rasmussen 2014), which are more aligned with translational researchers' interests. Some of the opportunities relate to how translational research is relocating animal research within a wider context of organisational practices and research skills. The new BPS core curriculum concerning the use of research animals includes training that puts knowledge, skills and attitudes about animal research into context. However, it no longer requires undergraduate students to undertake hands-on research with animal in education settings[6]. This decision was part of the harm-benefit analysis around the use of animals in education that the report facilitated, suggesting that learning outcomes at this stage could be achieved through observation, using simulations or videos, or through working with an animal facility where research is ongoing.

Our study adds further dimensions to the accounts of what constitutes 'good' animal research in STS with which we started. Striving for good translation can be understood through the notion of "good science" developed by Charis Thompson, in which scientific and ethical practices are understood to be "mutually entwined" (Thompson 2013). Thompson's articulation of good science centres on stem cell research, where she argues that "ethical concern lies at the heart of innovation" (Thompson 2013, 221). In the case of pre-clinical animal research, striving towards translation involves raising questions about model reproducibility and validity, rather than standardisation; connecting care for animals with care for patients; and balancing the reduction in harms to animals with the potential benefits in clinical practice. These questions about the planning, conduct, and outcomes of scientific research are important in driving innovative practices but cannot be resolved by adhering to (external) ethical guidelines and norms. Training for 'good' animal research requires attuning experiments to complex contexts, learning what matters to different bodies, and interpreting statistics and ethics in situ. Many researchers valued taking part in this research as an opportunity to reflect on their experiences of being trained, developing research careers, and informing the next generation of pre-clinical pharmacologists. Their accounts of what makes good pre-clinical animal research links science and ethics,

encompasses policy and politics, and draws on individual beliefs and conduct. Good translation is enhanced by this reflexivity. The recommendations to the BPS aim to generate researchers able to construct their research practice and collaborations in ways that support the multi-directional forms of attention that support translational research. Working collaboratively with social scientists has helped to identify and enhance these opportunities in future training for translation.

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[1] See for example Rader (2004) and Kirk (2008). For a detailed overview of the historiography of animal research, see Ankeny and Leonelli (2018).

[2] https://web.archive.org/web/20191016093215/https://www.bps.ac.uk/-educati-on-engagement/research-animals/curriculum-for-the-use-of-research-animals/ab-out-the-curriculum-for-the-use-of-research-anima, retrieved 16th October 2019.

[3] These kinds of animal models can be produced by surgical intervention (for example, removal of most of the pancreas, a pancreatectomy, to induce hyperglycaemia and symptoms of type 1 diabetes in pigs, dogs and non-human primates; King 2012); chemically-induced (the injection of the neurotoxin MPTP

into cats to simulate Parkinson's disease, Schneider and Markham 1986; Schneider, Yuwiler and Markham 1986); naturally-occurring (e.g. homozygous mutations resulting in obesity in mice, as a model of obesity; Lutz and Woods 2012); environmentally-induced (e.g. raising mice in obesogenic environments to make them obese; Lutz and Woods 2012); and produced by genetic modification by knockout of genes or transgenesis, the introduction of DNA into the genome (e.g. the transgenic mouse with mutant SOD1, a model of amyotrophic lateral sclerosis; Julien and Kriz 2006).

[4] P-hacking involves generating a large amount of data then conducting statistical analyses to find statistically significant relationships between variables without an a priori hypothesis.

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Self-tracking Technologies and the Menstrual Cycle: Embodiment and Engagement with Lay and Expert Knowledge

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Abstract: The paper explores how humans intra-act with self-tracking technologies, reconfiguring the plurality of expert and lay knowledge. In particular, the current contribution presents an empirical analysis of the use of apps to manage menstrual periods. The article is positioned at the crossroad between three literatures: actor-network theory; new relational materialism; and a sociomaterial perspective on the medical field as relates to self-tracking practices. These approaches contribute to pay attention on the processes of embodiment and embodied knowing situated into sociomaterial practices. The aim is to explore how the body learns "to be affected" through the material entanglements between humans and apps, and how self-tracking technologies are engaged and provide support for processes of embodied knowledge. Research findings draw attention to how interviewees intra-act with apps for menstrual tracking, along an imaginary continuum at whose opposite points we can find – on the one hand – minimal engagement with the knowledge inscribed in the app and – on the other – an affective engagement with the knowledge *suggested* by the app. This continuum shows the overlapping intra-actions that perform embodied knowledge about how women fertility, subordinate to the various historical stereotypes, works.

Keywords: self-tracking practices; embodiment; body; engagement; humans and non-human actors; intra-actions.

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1. Introduction

Digital technologies offer new possibilities for monitoring, measuring and visualising bodily and everyday wellbeing, potentially encouraging the development of new forms of engagement between human and non-human actors. The range of these technologies is vast: apps available for downloading to mobile devices such as smartphones; wearable technologies such as Google Glass and Fitbit; and sensors embedded in devices that can record both an individual's biometric information (e.g., body temperature, heart rate, blood glucose, etc.) and, in the smart city, various aspects pertaining to the health of that environment (e.g., air pollution, traffic, etc.) (Bianchieri *et al.* in Corbasiero and Ruspini 2016; Lupton 2013; 2015; 2016; Maturo and Setiffi 2016; Pantzar and Ruckenstein 2015). Self-tracking technologies allow users to monitor and document a great deal of daily information, practices and activities: calorie intake, fitness, weight, mood, sleep, reproductive health, chronic disease, healthy environment, and so on. Everyday practices and activities, as well as bodily functions, are transformed through these devices into data, with the potential to derive statistical analyses and graphical representations.

The aim of this paper is to explore how humans intra-act with self-tracking technologies, reconfiguring the plurality of expert and lay knowledge (Barad 2003; Latour 2005). In particular, the current contribution presents an exploratory empirical analysis of the use of apps to manage menstrual periods. Self-tracking apps for the menstrual cycle are intended to map and transform everyday symptoms, mood and body indicators into data – statistics and graphs – in order to visualise correlations and predict fertile moments, premenstrual syndrome and future menstrual windows (Lupton 2015).

Menstruation history is linked to a body of tacit knowledge (Polanyi 1967) based on myths, taboos and gender discrimination, often justified by medical research on hormonal biological changes (Delaney et al. 1988). In the sociological health literature, there has been extensive discussion on the transformation of symptoms and mood relating to menstruation into medical problems, with the emergence of the category 'premenstrual syndrome' (PMS). [1] Medicalisation is a complex and multidirectional process 'by which nonmedical problems become defined and treated as medical problems, usually in terms of illness and disorders' (Conrad 2007, 4). In many societies, for example, PMS does not exist. This implies that medical knowledge is socially constructed, because a disorder is not "ipso facto a medical problem" (Conrad 2007, 146). Moreover, feminist scholars have highlighted how medical knowledge is based on the assumption of male physiology as normative, with the consequence that women's bodies and experiences are particularly susceptible to the medicalisation process (Bird et al. 2010).

The paper is constructed around two concerns: (1) how the body learns "to be affected" through the material entanglements between humans and apps, and (2) how self-tracking technologies are engaged and provide support for processes of embodied knowledge.

First, this article outlines the theoretical-interpretative framework, drawing on actor-network theory (Latour 2005; Law 1992); new relational materialism, with particular reference to the feminist onto-epistemology of Barad (2003; 2007); and a sociomaterial perspective on the medical field as relates to self-tracking practices (Lupton 2018). These approaches have the common interest in the body, and together they contribute to pay attention on the processes of embodiment and embodied knowing through sociomaterial practices. Secondly, it reconstructs the debate around the use of digital data by second and third parties with the scope to surveillance and shape the habits and the bodily information of citizens.

Then, research findings draw attention to how women interviewed intra-act with apps for menstrual tracking, along an imaginary continuum at whose opposite points we can find – on the one hand – minimal engagement with the knowledge inscribed in the app and – on the other – an affective engagement with the knowledge suggested by the app.

Finally, the discussion of empirical findings highlights these two forms of engagement by which the embodied knowledge of the menstrual cycle is back through material engagements between humans and apps.

2. Embodiment and Self-Tracking Technologies

Self-tracking practices are reconfiguring our experience of embodiment, our relationships and our meanings of body through various practices of quantification. Self-tracking technologies have given rise to Quantified Self-movement (QSm), founded in 2007 by two editors of *Wired*, Gary Wolf and Kevin Kelly. The QSm motto is 'self-knowledge through numbers', to underscore the capacity of data to become a mirror reflecting imperceptible bodily functions, activities and practices otherwise taken for granted (Wolf 2009). According to Pantzar and Ruckenstein (2015), the voluntary self-tracker considers the data thereby derived to be more credible and objective than his or her own sensations and subjective experiences. Self-trackers experiment on their bodies through the emergence of 'personal analytics', i.e., practices that typically aim for self-optimisation (Moretti and Morsello 2017). Personal analytics practices transform human bodies into data with the purpose of reflecting in an objective way on themselves, others and on daily life.

Most particularly, self-tracking technologies are designed to be used in synergy with the body. This underlines the new intimacies of bodies and objects (Viseu and Suchman 2010). According to Knorr-Cetina (1997), objects take part in the co-constitution of social performances, in

which they have situated meanings and uses. The author posits an *object-centred* sociality, underlining a growing orientation towards objects as sources for thinking about Self, forms of relational intimacy, shared subjectivity and social integration.

Adopting a materialist perspective allows us to see the body as flows of heterogeneous sociomaterial elements that are relational and dynamics. The sociomaterial approach implies that the social and the material are co-constituted, namely that the nature and the culture are entangled. The humans are always situated in assemblages of heterogeneous elements, that have an agential capacity to affect producing power and resistance, tensions and ambivalences. A central aspect of the sociomaterial assemblages is that the matter is itself performed by the sensing and embodied knowing, showing the engagement of people with forces, things, bodies and other entities as entanglements of more-than human worlds (Barad 2003; Latour 2005; Law 1992)

We are immersed in assemblages where we learn to use the body to become sensitive to the materiality. As Latour (2004, 205) underscores, "to have a body *is to learn to be affected*, meaning 'effectuated', moved, put into motion by other entities, human or nonhuman" (original emphasis). The materiality is able to render the body sensitive to the differences of the world. The body feels and it moves. It is not finishing with the skin, but it encounters, tastes, hearings, smells other material elements. It is *affected* by the 'effects' of the knowledge, which is embedded and embodied within practices, by which we do experience of time and space. The body is enacted in various ways, continually being constructed through processes of incorporation and exclusion (Mol and Law 2004). Reciprocally, the body shapes how practices are done, and practices produce new responses across the process of producing sensible knowing in which body do not have determinate boundaries, rather it is co-constituted as an entanglements of relational and dynamics agency (Latour 2005; Lynch and Cohn 2016).

From a feminist materialist perspective, matter acts in assemblages in which human subjects are entangled with technologies (Lupton 2018). Boundaries between humans and non-human, as Barad (2003; 2007) argues, are not naturally given but rather historically co-constructed. The author proposes using the term 'intra-action' instead of 'interaction' in order to take into account the mutual constitution of humans and non-humans. This term is a way to reconsider the ability to act within relationships and not outside of them. In this regard, she uses the form "agential realism" to keep attention on the process in which the agency of subjects and objects acts symmetrically in the production of social and material worlds. The body emerges in ongoing discursive-material practices: "'We' are not outside observers of the world. Nor are we simply located at particular places *in* the world; rather, we are part *of* the world in its ongoing intra-activity [...] we know because we are *of* the world" (Barad 2003, 29-30).

Self-tracking technologies may be considered as objects of knowledge (Knorr-Cetina 1997) that are invested with expert and tacit knowledge related to embodied knowing that is multi-situated at the same time in materialities and discourses, but also in personal bodies and in their experiences. The intra-actions as bodily/materiality articulations perform various modalities of embodiment mediated by conventions and traditions. The term 'embodiment' enables a discussion of how the dichotomies mind/body and nature/culture are blurred in the materiality of the bodies. Adopting Scheldeman's (2010, 145) definition of embodiment as "the way we live life 'embodied': with and through our bodies" allows us to regard embodiment as a process by which the lived body becomes a material-discursive phenomenon that comes to matter in the mutual constitution of entangled agencies. The aim is not to extend subjectivity to things. As Suchman (2008) emphasises, humans and non-humans are not necessarily constituted one another in the same way. Agency does not pre-exist separately, instead, "agency – and associated accountabilities – reside neither in us or nor in our artefacts, but in our intra-actions" (Suchman 2008, 8).

Digital is material itself that becomes part of ongoing entanglements across a range of everyday activities and practices that combine diverse types of knowledge and capture our everyday spatiality. Here, self-tracking practices help us see not only the entanglements amongst things, people and data, but also and how these come back through new sociomaterial forms embedded in the ongoing self-knowledge process (Pink and Fors 2017; Sumartojo et al. 2016).

Agency is relational and distributed through intra-actions and entanglements of people with technologies. Particularly, humans and apps work together in generating human-app assemblages (Lupton 2018), in which knowledge emerges as a doing situated and enacted within and across humans and nonhumans. In our case, apps for menstrual cycle inscribe assumptions about users and what they will do with the apps, that have been designed in order to suggest knowledge about how the body should be working. However, humans and nonhumans generate together agential capacities and forces that are continually reconfigured as part of the lived experience (Lupton 2018). Apps directed at monitoring the body inscribe knowledge that can be reconfigured through the daily-human-use of the app. The process of reconfiguration draws attention to how inscribed knowledge can suggest different ways to think about the body. People who do not meet the inscription associated with the imagined uses can activate different ways of tinkering with the ongoing process of embodiment and selfhood.

3. Surveillance in a Datafied Space

The use, online and offline, of digital technologies leaves traces of personal preferences, choices, habits and so on. These small data, generated with and through digital technologies, are often aggregated into big data, and thus become commercially profitable for second and third parties. Some scholars (Kitchin and Dodge 2007, 2011; Kitchin 2014) have highlighted several important implications and issues concerning access to and control of small data. Most designers and developers of apps are very unclear about how the data are gathered, analysed and then used in terms of becoming a kind of 'dataveillance' to generate predictive health scores for users as well as preferences and choices for shaping human behaviours (Beer and Burrows 2013; Bossewitch and Sinnreich 2013; Boyd and Crawford 2012; Kitchin 2014; Mann and Ferenbok 2013). The term 'dataveillance' is used to indicate the systematic employment of digital data to surveil and monitor the practices and activities of individuals or groups of people (van Dijck 2014). Thus, for example, a smartphone becomes an assemblage of personal information, algorithms, websites, platforms, manufacturers and retailers, policymakers, software and hardware developers, etc. It is a black box that renders invisible the process of dataveillance by which the personal information thereby gathered can easily be analysed and grouped into discrete categories (Lyon 2002).

When citizens voluntarily collect and share their personal data and evaluations of various aspects of their social life and urban environment, they contribute to various scientific research projects and policymaking. They become data gatherers from below with the emergence of a 'datafied space', that provides a set of possibilities for how and where things can (or cannot) materialise. Some persons choose to participate in scientific research projects, collecting data that are quite important for scientists. These initiatives directly involve citizens who collect health indicators from their local environment, themselves or a combination of both. Cities and bodies become expanded laboratories in which citizen-scientists take on a crucial role for scientific and governmental organisations in the empirical phase of collecting observations and measurements for free (Coletta et al. 2018; Kitchin 2014).

In particular, Jennifer Gabrys (2014) underscores the emergence of new practices of subjectification through various uses of digital technologies. Citizens can monitor and evaluate their own wellbeing and environment, becoming sensitive to various aspects of life. According to Gabrys, there is a distribution of relational power in the city, where citizens are not just surveilled: they can also control their spaces with the emergence of new practices of citizenship.

Dataveillance has become a salient topic for theoretical reflection about self-tracking practices. Herein, this theoretical framework is

presented in order to illustrate the complexity around the analysis of how digital data are embedded into more-than-human practices. However, the focus of this contribution is on the sociomaterial entanglements between humans and apps.

4. Methodological Issues

The development of Web 3.0 – the 'intelligent Web' that uses semantics, natural language, data-mining and machine learning in order to provide a more productive and intuitive user experience – is intensifying the production of data on different aspects of everyday life. Some authors refer to this explosion of digital data as a 'data deluge' (Savage and Burrows 2007) that brought the opportunity to rethink everyday practices and routines in a datafication process by which human behaviours, emotions and social relations are recorded and converted into numbers (Roberts et al. 2016).

Fifteen semi-structured interviews had been carried out with women who utilize the app to manage menstrual periods. The semi-structured interview is a performative research method that can produce knowledge through the relationship between interviewee and interviewer (Law 2009). During the sessions, the interviewee became an ally in the process of questioning and opening the black box of the knowledge inscribed in the app (De Vita et al. 2016, 510; Sciannamblo 2017). This follows the suggestion of Mazzei (2013) that the interview yields sociomaterialist insights that can be thought of as an assemblage in which participant voice "is produced in an enactment among researcher-data-participants-theory-analysis" (p. 739).

The interviews were conducted with fifteen Italian women aged between 15 and 46 years, three of which were done via Skype. Lasting between fifty and sixty minutes, they were audio recorded and verbatim transcribed in order to analyse how apps for the menstrual period are embedded in the user's bodily knowledge. The interviews was intended to examine four principal concerns: (1) the choice of application; (2) the relationship between body and menstrual period; (3) the sharing of personal data with other users, parents, friends, partners; and (4) the sensibility about issues of privacy. The interviews were additionally enriched by using the app in real time in order to join the story of use at the practice of use.

Following an abductive approach, the analysis of the interviews aimed at generating creative, causal links and descriptions of particular empirical instances (Timmermans and Tavory 2012). Adopting an abductive analysis suggests entering the field with a theoretical framework that becomes the basis for developing creative and novel theoretical insights throughout the research process.

> In other words, abduction is the form of reasoning through which we perceive the phenomenon as related to other observations either in the sense that there is a cause and effect hidden from view, in the sense that the phenomenon is seen as similar to other phenomena already experienced and explained in other situations, or in the sense of creating new general descriptions (Timmermans and Tavory 2012, 171).

The analysis captures two forms of engagement between human and non-human actors. The following sections draw attention to how interviewees intra-act with apps for menstrual tracking, along an imaginary continuum at whose opposite points we can find – on the one hand – minimal engagement with the knowledge inscribed in the app and – on the other – an affective engagement with the knowledge suggested by the app. This continuum shows the overlapping intra-actions that perform embodied knowledge about how reproductivity works.

5. Minimal Engagement

Women have to learn to control personal cyclical spotting that is different in duration and flow. Keeping track of the cycle's length through a diary and calendar, as tacit knowledge suggests, requires a certain amount of time and commitment (with the purpose of estimating future periods). The app translates the necessity of managing the beginning and the end of the period as a means of deriving an automatic prediction of future menstrual phases.

The example that appears through the various interviews relates to the need for an automatic memorandum that offers the possibility of eliminating thinking about the cycle from the daily agenda. This is the principal cause of engagement in the materiality of the app. For example, Adele explains how she has used it:

> I started using it because I'm a big mess and I often forgot to mark it on the calendar… even with the app I'm a mess, but with the app I tend to be less [because] when I think that the period is coming, I open the app and check the previsions. So, I use it to know easily when the period is back. Let's say, so I can organize me… (Adele, age 46)

The app supports human organisation. It is easy to note the beginning and end of the period, because the smartphone is already incorporated in our lives. The app automatically organises the messy calendar to visualise the chronology of the cycle through 'objective data' that can be used to manage all the inconvenience linked with monthly spotting. For example,

Chiara recounts how she has decided to replace the paper agenda with a digital one:

> It happened that I was at a conference and the cycle arrived unexpectedly. I mean, I did not remember it properly... but it was quite problematic because I had to present my research in public… hence, there were several factors of annoyance and then I thought that... I mean, if I note down in the diary then I forget to check, maybe I'm not looking. And I thought this thing of the app... that is, the thing that I find useful is that it has a calendar so if I click on the calendar, I visualize the whole chronology of my cycle since I downloaded it. (Chiara, age 38)

The diary needs to be fixed and the notes have to be checked. In contrast, the app easily creates statistics and provisional data on the basis of biological data collected by the woman. Self-tracking practices bring back the material aspects of menstrual cycle, rendering the body sensitive to the differences of biological changes. The body is translated in digital information, even if the woman does not record all the informational demands of the app. The following extracts pay attention to the different ways through which the women interviewees embed the app in their lives on the basis of different outlooks and necessities. It depends on their knowledge about how reproduction works, so on engagement with the knowledge inscribed in the materiality of the app.

For example, Jasmina does not understand why she should record her mood, symptoms and temperature, her cervical position or mucus amount. She does not know how this information can be useful to create a more reliable prediction of fertility and ovulation windows. It is interesting to underscore that she opens the black box of statistics and average menstrual and fertile windows only during the interview. Statistics and averages are produced on the basis of a chronological report of past menstruations. These functions produce data that can be visualised only if the user tinkers with the app in order to understand how it works. Before that, Jasmina had never tinkered with the app and she did not know that it could be used to record all that information. She says:

> We can see it… that is, I don't really like this app, but I'm accustomed to use this one. See, you can record symptoms, mood, test results, contraceptives used… all these things, a little bit weird… maybe… let see, reports, predictions, chronology, sexual activities, temperature? Symptoms? Let's see, it tells you how many times you recorded this symptom in the past thirty days. I mean, it does graphs, too. But, I don't know… why I have to record all these data? Maybe I didn't invest time to understand why I should to collect these data… (Jasmina, age 27)

In this case, the interview become an ally in the intra-actions between the interviewee, knowledge of her fertility and the knowledge inscribed in the app. This extract shows the minimal engagement of Jasmina in the materiality of the app. She had not questioned the knowledge inscribed in it because she only needed a memorandum of the beginning and end of the menstrual window.

Minimal engagement with the knowledge inscribed in the app also depends on the gender stereotypes linked to menstruation. It emerges that menstruation is a 'thing' that needs to be made invisible through the materiality of the app. Chiara recounts that, when she downloaded the app, she looked for one that did not seem to be obviously a program to track periods:

> The icon is violet with a drawing of the number twenty-eight. I think that is regarded as the menstrual period's length. By the way, I was looking for an app that didn't look like female stuff for menstrual period… I just felt weird that someone could see stuff for my period on my smartphone. So, when I chose it, I thought about the icon, too. (Chiara, age 38)

Another example that underlines the impact of gender stereotypes about use of the app is the consideration that reproductive knowledge becomes an issue only if a woman is seeking to become pregnant. Contraception is based on methods such as the pill and condoms that ensure protection without worry about the regular change that occurs in the female reproductive system. Each cycle can be divided into three phases: follicular phase, ovulation and luteal phase. These changes can be altered using hormonal birth control such as contraceptive pills. The use of these contraceptives is not linked to the need to think about hormonal changes. Acknowledgment of the ovulation phase is considered over-information because, as Palmira says, it is not necessary to know our hormonal changes when you can employ ready-for-use contraception:

> I don't understand… I mean, there is written fertile and ovulation window. I mean, I know that in the ovulation period you could have some spotting. Or maybe… I remember that spotting should be between the two phases. However, since I don't want to get pregnant, I am not interested to understand these things. I mean, I don't want to get pregnant, so I am not interested if I am fertile or not. Maybe it is very useful for women who want to get pregnant. (Palmira, age 20)

The richness of this extract shows that the interviewee has not questioned the medical knowledge inscribed in the app. She has confused knowledge about fertility and ovulation and uses the interviewer's presence to tinker with the artefact. The materiality of the app provides the possibility of using it to better comprehend one's individual

sensibility. Palmira is subordinated at the historical stereotypes about menstruation seen as a reproductive business that can become an issue only while trying to get pregnant. Until that time, it is important to know cycle length to understand if it is regular or not and, consequently, to control it.

Here, it is possible to underscore that even minimal engagement in the intra-action with the app can produce knowledge reconfiguration. The knowledge reconfiguration gives rise, for example, to greater awareness of one's cycle length. Even if the app is used only for noting the beginning and the end of menstruation, its capacity to produce averages and predictions can enhance and extend knowledge of the user's own cycle, as Palmira explains:

> I knew that my cycle was coming because that I had a traditional backache, so I didn't need the app. But I realized that my period was irregular, and I thought 'let me understand how much it is random'. Then I began to use the app in order to understand my irregularity. And I had realized through the average produced by the app that my period is about 35 days long. So, I utilized it just to understand my period's irregularity… my friends are so regular, they don't need the app. (Palmira, age 20)

This extract shows how minimal engagement produces minimal knowledge reconfiguration. The minimal reconfiguration knowledge is linked to awareness of the cycle's length. Now Palmira knows that her cycle is 35 days long. However, she is convinced that her period is irregular only because it is not 28 days long, even though medical knowledge affirms that menstruation is regular if it occurs anywhere along a 21- and 35-day cycle. In this sense, Palmira has not questioned her knowledge that is linked to the myth of regularity that defines a cycle as normal only if it is 28 days long.

Here, self-tracking practices show how the materiality and sociality act symmetrically producing different uses of the app in everyday spaces. The materiality of statistics and graphs produces different means embedded in the knowledge about one's own cycle, which at the same time act in the ways in which the app is used.

6. Affective Engagement

This section shows how the entangled agency between humans and non-humans can produce overlapping forms of intra-action by which both personal and expert knowledge are reconfigured. Here, attention is directed to the form of engagement embedded within reflexive tinkering with the expert knowledge suggested by the app. The agency of the app emerges through its capacity to make visible how fertility should work on

the basis of the data recorded by women. The body is broken down into a series of symptoms such as acne, back pain, headache, change in mood, identifying traces of sociomateriality left by statistics and graph.

The principal characteristic of affective engagement is recognising that the working of the app depends on biological knowledge that becomes visible in the concrete daily experience. The body is 'learning to be affected' through tracking some symptoms. The interviewees are becoming more sensitive to recognising various changes in their bodies as linked to menstrual phases. Even if they know their menstrual symptoms and mood, the app provides proof of such connections. In this regard, Maia says:

> At first, I recorded symptoms and other things because I wanted to understand. I mean, I thought: 'Maybe these symptoms such as headache and back pain are regular, maybe they reappear in the same way'. So, I kept a note. But now, I'm sick of recording this information. I just don't really have time for the app, either. But sometimes I record it if I have a bad headache or particularly strong pain. Then if it occurs again, I can say: 'Well! It was because of my cycle!' […] I mean, I like to know when I am in the max period of fertility because I know that it is linked to some symptoms, like spotting, etc. I like to know if they are linked to my cycle or not. (Maia, age 26)

Here, Maia collides with the suggestion to recognise PMS in some symptoms in her daily mood. She uses the app to track her symptoms and emotion, but this does not mean that she records all the information suggested by the app. To the contrary, she just tests her bodily knowledge to confirm some connections. After that, she embeds the app in a reflexive underutilisation, because she recognises when her mood or various symptoms are linked to her cycle; for this reason, she does not always feel the need to record that information. We can note how intra-actions between humans and non-humans translate agential capacities and forces by a setting of uses that take into account the materiality and sociality of the lived experience.

As a counterpoint, Adele monitors symptoms to confirm that she is on the threshold of menopause. In this case, the app is a repository of traces that make it possible to join to demonstrate an assumed awareness. She recounts:

> …seeing how much time, how many days my periods last, the amount of flow, on which days it is concentrated. Those are data I come back to. In fact, it is through the app that I have understood that my cycle has become shorter—for example, from 28 days to 25 or 26 days. When you can visualize this through statistics, you have a different awareness and possibly you are surer about your body. Indeed, among other things, it is more useful for giving me

> knowledge about my body. Because I have a coil, I have no problem controlling my cycle from that point of view, to control my fertility or not, or rather to become pregnant or not. Let's say, I'm quite… Yes, the app gives me further knowledge of my body, how it changes and how it is changing. (Adele, age 46)

This extract shows the agential relationship between humans and non-humans. The agency of the non-human actor lies in its capacity to produce personalised statistics that are reconfigured through self-tracking practices embedded in everyday activities. Some interview extracts show that women often play with the app even just for short periods or for some needs, such as when Ada was trying to get pregnant:

> It helped me because I more or less knew my fertile days. Obviously, it's not one hundred per cent sure! There must also be some luck. We succeeded immediately. I was pregnant by the second month! So, I don't know if it was the accuracy of the app or luck […] I recorded the times we had sex, so I could see more or less the two days in which I got pregnant, which were the two days close to my ovulation day. (Ada, age 31)

Ada knows how fertility works, pointing out that she is not sure about the accuracy of the information the app provides her. Maybe, if she had not used the app she would have obtained the same result. However, it gives her support in determining when she is in the fertile window, becoming an ally in her aim of getting pregnant.

If, in the previous extract, attention is on the possibility of visualising ovulation days, in the next the app can help to visualise how fertility works; as such, it can organise dates and thereby play an active part in contraception dynamics based on the use of a condom. Ofelia explains:

> I mean, before using the app, I didn't have exact control over at-risk days for having sex. I mean, I know that there are other ways of knowing that, because [name of app] doesn't discover anything. However, it's so much simpler with it. The cycle comes, and I just sign in, that usually it's already foreseen. Moreover, there is the possibility to track symptoms and… Look how beautiful! You can track everything, even acne. But, when I have a partner, I often need to know if I will be in my period or not in order to organize, you know... I mean, it's simpler to organize. Obviously, if you use a contraceptive method, you don't stop using it. But, I mean, it can be useful, that is, it's better to know. So, you are even more aware of your body than your relationships. (Ofelia, age 25)

Ofelia has biological knowledge about how a woman's body works, and she recognises this knowledge in the app's materiality. She knows that the prediction of fertility and ovulation windows depends on

biological mechanisms that could be calculated manually with the use of a calendar; however, she had never calculated her ovulation days prior to obtaining the app. Ofelia's affective engagement is embedded in her reproduction experience of a 25-year-old university student who thinks about her reproduction only in order to avoid pregnancy. The app is considered an enhancement to the use of the condom, becoming a contraceptive itself.

The same function can be used in different ways, as suggested by Chiara's experience. Chiara is 38 years old with high investment in her academic career. She has postponed having a child, thinking that one day she will satisfy her need for motherhood. But now that her reproductive life is approaching the menopause phase, she knows there is a high probability that she will fail in her desire to have a child. Here, the function of visualising the ovulation window becomes a way of reflecting on the body in relation to reproductive and sexual life, as Chiara explains:

> My awareness has changed regarding a whole series of things! For example, since I was not trying to get pregnant – at this precise moment, I don't even have a partner […]. I never even thought about using the Knaus-Ogino method as a contraceptive. The whole story of when I'm ovulating, I mean, awareness of when I was ovulating, I would have preferred not to have this awareness. […] I don't know how to explain… the app doesn't produce any kind of changes. It's not that… It's the fact that displaying certain types of information makes it hard not to think about it. So, for example, since I've been using this app, every time it tells me 'today is a fertile day' I'm thinking, 'another day of my life that hasn't been used'. I don't change my mind or do different things, but… (Chiara, age 38)

Here, Chiara embeds the visualisation of ovulation windows materialised through statistics and graphs in her ideas about motherhood. She sees the averages and the forecasts as unfertilised eggs. In this sense, the use of the app is embedded in her thoughts about fertility, ovulation, motherhood and gender discrimination regarding PMS definition. She says:

> For example, when I take the pill and the app tells me 'You're ovulating', I think 'What a fool!', I mean, it's not very rational […]. Then it says 'PMS', which I imagine means premenstrual symptoms. But I think this is a sexist thing, as it never occurred to me to record whether I had symptoms. (Chiara, age 38)

It is interesting that Chiara uses human language to make fun of the app. She tinkers with the non-human actor with complaints about the definition itself of PMS, since recording symptoms and mood reproduces and thereby keeps alive sexism and taboos around the female period.

In this second engagement form, the body comes to matter within an effective engagement between human and non-human actors. The agency of the app performs the recognition of some bodily elements otherwise taken for granted. On the other hand, the women interviewed tinker with the suggested knowledge about how the body should work. The result is an affective engagement of apps and bodies, which become more sensitive to understanding menstrual phases.

7. Discussion and Conclusion

The two forms of engagement analysed in previous sections are considered as a continuum whereon overlapping intra-actions can produce different experiences of embodiment.

Tracking menstrual cycles can bring back the materiality of hormonal changes. Analyses of these engagements illustrate how bodies learn into dynamic assemblages in which, reciprocally, body shapes how practices are done, and practices produce new responses performing the body in both social and material ways (Lynch and Cohn 2016). The result is that self-tracking practices emerge as part of ongoing process across a range of everyday activities, combining diverse types of knowledge.

The first form of engagement embeds the necessity to control the beginning and the end of menses on the basis of biological knowledge that, inscribed in the materiality of the app, provides an algorithmic memorandum. The second implies a reordering of the knowledge suggested by the app, rendering alterations within the body affected at the various meanings that could express hormonal changes. This interpretation is sustained by the difference that emerges from the interviews between inscribed knowledge and suggested knowledge. In the first case, interviewees recount how they use the app, describing it as a black box that produces predictions about the next menses. They have not questioned how tracking menstruations could be the result of a materiality that incorporates biological knowledge about how the menstrual cycle should work and, as well, developers' assumptions about users and how they should use the app. Self-tracking practices replace the use of pen and calendar, becoming part of the women's tacit knowledge about bodies and menstruation (Polanyi 1967; Scheldeman 2010). In the second case, women tell about how they tinker with the device, seen as a repository of inscribed knowledge that suggests different ways to think about their relationships and, further, meanings of their own body-as-lived. Here, menstrual tracking becomes part of the process by which body 'learns to be affected' by entanglements of humans and nonhumans (Latour 2004).

The two forms of engagement assume diverse nuances in thinking about the body. The extracts of the first form analysed describe a

confused knowledge about fertility subordinate to the various historical stereotypes. Here, it is important to know cycle length to understand if is regular or not (and thereby control it). Some of the interviewees do not care about how the app works, since they do not know all its functions; they use the interviewer's presence as an ally to understand the knowledge inscribed in it. The extracts of the second form describe the process by which knowledge inscribed in the app becomes a way to think about fertility, ovulation, motherhood, PMS and gender stereotypes. In this case, the visualisation of ovulation and fertility windows is embedded into daily experience whereupon the body is continually reconfigured as part of the lived experience (Lupton et al. 2018).

Regarding this point, it is important to note that the interviewees emphasise the difficulty of trusting in the suggested knowledge. The dynamics of ovulation remain invisible, and for them a graph or an average cannot represent the reality of the biological mechanism. The interviewees underscore the challenge of recording all the information requested by the app, even though it allows them to reflect on some connections otherwise taken for granted. Here, we can see how the boundaries between humans and non-humans are co-constructed and tied to heterogeneous elements. So, rather than delineate what capacities are human or technological, analysing self-tracking practices as embodied knowing helps capture how humans and app act together in the construction of entangled agencies.

This interpretation is also sustained by the examples presented in the section on affective engagement with the materiality of the app. Even though the application suggests knowledge and practices, women play with it even for just a few moments or periods or, alternatively, for specific necessities, such as when Ada was trying to become pregnant. She knows that she would maybe have obtained the same result without the app's use, but it becomes an ally in the acknowledgement of her ovulation phase. In particular, even though self-tracking technologies are designed to act in synergy with the body in order to produce reliable data, the extracts analysed reveal the mutual translation between what the app suggests monitoring and what the woman actually tracks. It is important to draw attention to the constant renegotiation between how the app should be utilised and how it is used in real-life experience. As we have seen, agency is relational since the app enacts expert knowledge that acts to produce graphs and statistics. At the same time, women record only that information considered useful in the economy of their everyday lives. Here, we can see the process by which the agency of subjects and objects act symmetrically, producing data that are co-constructed into human-app assemblages (Barad 2007; Law and Mol 1995; Lupton 2018).

The intra-actions between interviewees and apps standardize symptoms as acne, tender breasts, bloating, feeling tired, mood changes across the materiality of graphs and statistics. The affective engagement

with the materiality is able to render the body sensitive to recognise some menstrual signs, which emerge as the result of intra-actions between knowledge inscribed in the app and tacit knowledge embedded in human corporeality. As Maia said, knowledge inscribed in the app suggests that tracking symptoms and signs can derive demonstrable proof of the connection with one's upcoming menstruation. In addition, the affective engagement in one's cycle and its fulsome implications can be embedded into not using of some functions in order to contrast, as Chiara explains, the assumptions inscribed in the app. She tracks just the beginning and the end of menstruation because she complaints about the definition of PMS, since recording symptoms and mood is a way of sustaining sexism and taboos around the female period.

Even if self-tracking practices produce data that women voluntarily collect in a fragmented way contrary to the real developers' design, they can be a resource for governments and markets (Kitchin and Dodge 2011; Kitchin 2014). The body is transformed into digital data through practices that people enact within power relations that exist into assemblages of humans and nonhumans.

Power is based on surveillance, incorporated in the governance of citizenry and internalised by actors. Analysing self-tracking practices means observing how policymakers and health authorities alike could gather personal information and create discrete categories (Lyon 2002). In our case, data on fertility, ovulation and the menstrual cycle, produced through an app, can be used not only by employers, but also by governments, to monitor the state of pregnancy and, further, estimate the duration of maternity leaves for female workers[2].

However, subjects are not just surveilled, they also respond and reconfigure the dominant ideas and norms of environment. The spaces of everyday life become expanded laboratories in which individuals take part in the dynamic of power relations through a range of different practices (Gabrys 2014; Coletta et al. 2018). Here, self-tracking practices emerge as a way to enact different meanings of the body's engagement in the ongoing process of subjectification. This engagement comes back into diverse materiality ways as the product of overlapping intra-actions between humans and nonhumans, in which digital technologies are situated into practices that enact a knowing embodied.

Adopting a sociomaterial lens suggests analysing the self-tracking practices as part of entanglement of people and technologies, showing how the experience of menstrual cycle tracking is an embodied, more-than-human practice. This allows to pay attention on the complexity and heterogeneity of uses that often differ from their expected utilization, rather than trapping such experiences within discourses that emphasise a range of issues relating to data surveillance.

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[1] Even if the focus of this contribution is not on the constitution of PMS as a medical syndrome, it is interesting to note that this term is frequently used, especially in the public debate, to report or justify a mixture of somatic and

psychological symptoms related to changes in the ovarian hormone levels that, notwithstanding an understanding of its exact etiology is still poorly described and documented. In some cases, PMS ends up being used as a means of questioning the capacity of women to manage and participate as co-equals to men in prestigious economic and political positions (Rittenhouse 1991). Symptoms are categorized as physical, psychological and behavioral. Physical symptoms include fatigue, edematous sensation, sinus sensitivity, headache, weight gain, muscle pain; behavioral and psychological symptoms include irritability, nervousness, mood swings, sadness, depression, hypersomnia or insomnia, decreased concentration.

[2] Particularly the press is beginning to emphasise that app's developers could sell data to second and third parties. For an overview, it is interesting to quote the articles available on the subject: https://www.washingtonpost.com/technology/2019/04/10/tracking-your-pregnancy-an-app-may-be-more-public-than-you-think/?noredirect=on&utm_term=.7833e7e2ec3f; https://www-.internazionale.it/video/2019/07/23/app-mestruazioni-marketing.

Reflections on Self-tracking Routines: Conducting Maintenance of Digital Data

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Abstract: Self-tracking technology is considered a critical learning and motivational resource that at best helps people self-reflect, thereby promoting attempts to make changes to lifestyle routines. This study examines how people incorporate this technology into their daily practices and the routines that self-tracking technology produces. The study is based on an in-depth empirical analysis of a sample of interviews of volunteer participants of a pilot study aiming to promote health and wellness. The interviews took place in two phases: first, after three months of self-tracking (in total 27 interviewees) and second, at the end of the pilot study after ten months of self-tracking (in total 21 interviewees). The analysis focused on the participants' reflections on their user experiences of a self-tracking device, the data that this produced and the resulting routines. The results suggest that people's self-tracking routines are often related to the maintenance of a visible and continuous data flow in self-tracking applications. Routines for wearing, tending to and communicating with self-tracking devices play an important role. These routines are either only remotely related or not necessarily at all related to making changes to lifestyle routines that affect health and wellness. The development of routines through novel artefacts involve much invisible work and can even lead to unintended consequences. During self-tracking, the focus may remain on the technology alone and on attempts to develop routines for maintaining a continuous, accurate flow of data, rather than on actually making lifestyle changes.

Keywords: routines; artefacts; health and wellness promotion; pilot study; self-tracking.

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1. Introduction

Health care settings are hoping for an overall shift in emphasis from routines of reactive treatment to routines of the proactive prevention of diseases and the maximization of people's wellness. These hopes are materialized in, for instance, emerging P4 medicine, which stresses the role of individuals' health data as predictive, preventive, personalized and participatory (Hood and Friend 2011). P4 medicine aims for behavioural changes to lifestyles that at best result in routines that add to health and wellness. People today are encouraged to actively collect their personal data because these are considered the "best (yet often 'untapped') resource for information" on themselves in general, and their own states of health and illness in particular (Wyatt et al. 2013, 132). Here, self-tracking devices that enable real-time tracking are considered important artefacts that support monitoring, documenting and analysing various aspects of daily life, such as activity and sleep, which affect health and wellness (e.g. Swan 2012). Self-tracking devices thus allow datafication, that is, the transformation of social action into online quantified data (Mayer-Schönberger 2013). The resulting personal data can act as a critical learning and motivational resource that at best may help people self-reflect and thereby improve their attempts to make changes to their lifestyle routines, in turn contributing to better health and wellness.

This study recognizes routines as patterns of action and refers to Feldman and Pentland (2003), who note that in addition to the routine in principle, i.e. the generalized idea of a routine, there is the routine in practice, i.e. the enactment that brings the routine to life. The role of artefacts is considered essential in the production and reproduction of routines (D'Adderio 2011). This is because they are seen to offer an 'invitation' for action simply by being there and being available (Callon and Muniesa 2005). At the same time, artefacts may act as important mediators or intermediaries in routines while organizing or even transforming the knowledge, skills and capabilities of their users (Latour 2005). As D'Adderio (2011, 210) points out, "the actor's knowledge, skills, and competences *depend on* – and are at the same time *configured by* – the tools and artefacts they encounter or involve into their routine performances". This does not mean that artefacts completely determine actions; instead, artefacts may act as an enabling or constraining source, making it easy and possible to do some things or difficult and impossible to do others, including the creation of particular routines (e.g. Orlikowski 1992).

The deployment of novel artefacts that support particular routines or even routine change is not, however, easy. The designers and promoters of behaviour change technologies face challenging questions not only regarding usability (can the users use the technology?) and user engagement (does the technology meet the users' needs?) but also on the long-term effects of the technology (Stawarz and Cox 2015). Thus, one of the key questions in terms of routines is whether the technology supports the de-

sired routines or routine change, in other words does the technology actually work for its user?

The existing literature has noted that self-tracking technology provides an infrastructure that "allows for both reflexivity and a creation of flexible routines" in a personalized manner (Lomborg and Frandsen 2016, 1019). At the same time, recent studies have acknowledged a lack of understanding of how people generate and interpret their self-tracking data, as well as of how they incorporate it into their daily routines (Pink et al. 2017; Lupton et al. 2018). Moreover, it is important to recognize that digital data may well be broken (Pink et al. 2018). This means that incomplete, inaccurate, contingent, fractured, or dispersed self-tracking data may affect the type of routines that self-tracking technology produces.

This study aims to contribute to the discussion on self-tracking routines through an empirical investigation of how the users of self-tracking devices reflect on their routines related to this technology. The context of the study is a large pilot initiative aiming to promote health and wellness. In the pilot initiative, the advancement of individuals' lifestyle changes played an important role, and to support the volunteers' attempts to record and potentially change their health- and wellness-related routines, in particular activity and sleep, they received an activity wristwatch, the Withings Activité Pop, which is a self-tracking device with a connected smartphone application (Withings Health Mate). This study is based on an in-depth analysis of a sample of interviews of the pilot study participants. The analysis focused on the participants' reflections on their user experiences of the self-tracking device, the data that it produced and the resulting routines. To obtain an understanding of how the participants incorporated this technology into their daily practices and the routines that the self-tracking technology produced, the interviews had two phases; first after three months of self-tracking, and second at the end of the pilot study after ten months of self-tracking. The interviewees consisted of three different types of pilot participants: those with no previous experience of self-tracking, those with extensive prior experience, and those who were extreme in their self-tracking.

The results show how in the interviews, the pilot study participants mainly reflected on the self-tracking routines that were related to maintaining a visible, continuous data flow in their smartphone applications. Some participants were also concerned about the accuracy of their data and tried to invent ways in which to gain more reliable data. The routines for wearing, tending to and communicating with their self-tracking devices played an important role in the participants' reflections. Interestingly, these routines were either only remotely related or not necessarily at all related to the original aims of the application of the self-tracking device in the pilot initiative, i.e. the improvement of activity and sleep routines contributing to health and wellness. The results thus suggest that developing routines through novel artefacts involves much invisible work and can

even lead to unintended consequences. Instead of promoting lifestyle changes, the focus may remain on the technology alone and the aim may be the development of routines for maintaining a continuous, accurate flow of data.

2. Self-tracking Routines

There are several disciple-specific literatures on routines. This study addresses the literature developed in organization theory, which recognizes routines as patterns of action. Feldman and Pentland (2003) have emphasized three interrelated and important aspects of routines; the ostensive and performative aspects of routines and the related artefacts. They define (2003, 101) the ostensive aspect of a routine as "the abstract, generalized idea of the routine, or the routine in principle". These can be taken-for-granted norms, normative goals, or may exist as codifications in various forms of artefacts consisting of guidelines, rules or templates for behaviour. Importantly, however, they remind us that such codifications are not unified objects; instead, people always have their own subjective interpretations and understandings of the ostensive aspect of a routine. Health and wellness promoters, for example, may consider self-tracking devices artefacts that contain a template for data collection routines that allows self-reflection and thereby potentially also the improvement of changes to lifestyle routines (see Lupton 2014). The subjective interpretations of device users, however, can vary from seeing self-tracking devices not only as a tutor helping in the formation of routines, but also as a tool to build statistical records, for instance, or simply a toy that is fun to play with (Lyall and Robards 2018).

The performative aspect of a routine, defined by Feldman and Pentland (2003, 101) "consists of specific actions, by specific people, in specific places and times. It is the routine in practice". They note that the performative aspect of a routine is inherently improvisational, as it can be adjusted to changing contexts. People may choose to use self-tracking devices in different ways in different situations. Studies show that people use self-tracking devices for various purposes; for example, to document their activities, to reach various goals ranging from behaviour change to effective training, to gain support for self-reflection and self-care, or to detect patterns and causal relationships in various health-related matters (e.g. Li et al. 2011; Rooksby et al. 2014). Artefacts that only contain ostensive aspects of routines become meaningless if the routines have no performative aspect. If people are indifferent to self-tracking data and do not find the use of the device meaningful at all, they may even abandon the device completely (Ledger and McCaffrey 2014; Nafus 2014).

Importantly, routines also contain internal dynamics. Feldman et al. (2016) note that in routines, action is always situated. This means that routines are always enacted at specific times and in places in particular

sociomaterial contexts. Pink et al. (2017), for instance, have shown how people appropriate their self-tracking practices into their cycling routines. Feldman et al. (2016) stress, however, that situated action requires a great deal of effort, and people need to be knowledgeable and often also reflective while accomplishing routines. It is not easy to generate the same patterns of action time after time. Instead, there is a constant struggle to deal with simultaneous pressures of replication (to copy exactly) and innovation (to make variations or changes) (D'Adderio 2014). Thus, as Feldman et al. (2016, 508) point out, "stability in routines is both a matter of perspective and a matter of time". They emphasize that stability is always an accomplishment, and at best, routines can only be stable at a given time. Ledger and McCaffrey (2014) have noted that many users completely stop using devices for self-tracking routines after a few months, which means that the devices do not necessarily succeed to drive long-term routine engagement.

Intentional routine change has been at the centre of many practitioners' attempts and is also the interest of research (e.g. Dittrich et al. 2017; Glaser 2017; März et al. 2017). Guidelines for healthy living, which are seen as advice for managing our bodies and lifestyle changes, are plentiful, and people often falsely consider changing everyday routines to involve simply, straightforwardly and easily putting knowledge into practice (Lindsey 2010). Routines change as a result of "people doing things, reflecting on what they are doing, and doing different things (or doing the same thing differently) as a result of the reflection" (Feldman 2000, 625). Reflective talk has shown to support routine change through envisaging and evaluating alternative patterns of possible actions as well as alternative ways of enacting a routine (Dittrich et al. 2017). The role of artefacts has also proved important in intentional routine change (e.g. Iannacci 2014; Glaser 2017; März et al. 2017). As Pentland and Feldman (2008) have shown, however, shaping routines through the design or implementation of novel artefacts is not easy, nor necessarily successful. As they note, the risk of failure is particularly high when artefacts are developed by those who do not participate in the routines themselves, and when the perspectives of those who enact the routines are completely ignored. As an example, technological artefacts are often designed only for particular versions of the human body: the action options of the same technological artefacts can be quite different, for instance, for a disabled body (see Scarry 1985; Bloomfield et al. 2010). The adaptation and customization of technological artefacts for better support of routines or routine change can also be difficult due to the 'power of default' of such artefacts (Koch 1999; Pollock and Cornford 2004; D'Adderio 2011).

To develop self-tracking routines, it is essential that people gain data that are 'lively', something that they can reflect on and consider somehow meaningful in their daily lives (e.g. Lury 2012; Lupton 2016). It is important to note that users of self-tracking devices do not perceive their data as uniquely objective and true, and self-tracking can produce a varie-

ty of meanings and values of data for people, from mindfulness and resistance to digital storytelling (Sharon and Zandbergen 2017). Similarly, self-tracking devices do not necessarily operate in a straightforward manner in health and wellness promotion: they may serve as conversation facilitators through the production of situated data that become meaningful through people's reflection on them in the context of their everyday lives (Pantzar and Ruckenstein 2017).

While using self-tracking devices, both experienced and inexperienced users may, however, experience serious difficulties in their attempts to track and reflect their personal data (e.g. Rapp and Cena 2016; Yli-Kauhaluoma and Pantzar 2018). Data collection and recognition of behaviour patterns and trends can be burdensome and time consuming (Li et al. 2011). Data interpretation, i.e. extracting meaningful information from self-tracking data, is not necessarily easy and may require clear tracking strategies or even various material workarounds (Choe et al. 2014). The users of self-tracking devices may even encounter data that are broken, i.e. inaccurate, incomplete, or dispersed across different digital platforms (Pink et al. 2018). This means that self-tracking devices and the data that they produce may require continuous maintenance and even repair routines. As long as the artefacts work, however, maintenance and repair routines often remain invisible (e.g. Shapin 1989).

Jackson (2014, 221) has noted that we ought to "take erosion, breakdown, and decay, rather than novelty, growth, and progress, as our starting points in thinking through the nature, use, and effects" of the artefacts around us in everyday life. The artefacts around us can be fragile (Connolly 2013) and they usually collect traces of consumption (Gregson et al. 2009). Object maintenance requires care tasks that entail both constant watchfulness (Denis and Pontille 2015) and user competences (Gregson et al. 2009). When breakdowns and malfunctions occur, they are not necessarily easily fixed (Graham and Thrift 2007); repair often involves situated interaction between the social world and material possibilities, which need to be examined carefully (see Jarzabkowski and Pinch 2013; Mitrea 2015). The digitality of objects complicates things even further and undoes professional boundaries not only between making and using (Suchman 2014), but also between making, using and repairing (Denis et al. 2015). Tanweer et al. (2016) have shown that the maintenance and repair of digital data is ordinary work for those who are professionally involved with complex data sets. They show how working with digital data requires data manipulation, improvisation and even innovation for dealing with and repairing continuous data breakdowns.

3. A Study of Self-Trackers' Accounts of Routines in a Health and Wellness Pilot Initiative

The design and implementation of various types of health interventions in the form of pilot studies or trials (e.g. Hood et al. 2015; Lynch and Cohn 2015) has attracted great interest in recent years, to find solutions for increasing the levels of people's physical activity and to more generally promote healthy ways of living in modern society. At the same time, people are eager to learn more about themselves, their state of health and health risks, their connection to others, and even to contribute to research (e.g. Turrini and Prainsack, 2016). The empirical setting of this study is a health and wellness pilot initiative[1] in which the promotion of individuals' lifestyle changes played an important role. To obtain knowledge of the participants' state of health, various types of data, such as genomic, metabolomic, microbiome and comprehensive lifestyle monitoring data were collected in the pilot initiative from roughly one hundred healthy volunteer participants (see Neiman et al. 2019). The pilot organizer recruited the participants from the clientele of a private occupational health service provider. They were employees from four different large organizations. All the participants signed an informed and voluntary consent form for the study. The pilot initiative ran for sixteen months from October 2015 to January 2017.

To support the volunteers' attempts to record and potentially change their health- and wellness-related routines, particularly activity and sleep, the participants were 'pushed' into a self-tracking mode (see Lupton 2014). This means that self-tracking was taken up voluntarily but encouraged as part of the pilot initiative. The participants received an activity wristwatch, the Withings Activité Pop, which is a self-tracking device with a connected smartphone application (Withings Health Mate). According to the pilot organizers, the selected self-tracking device was chosen in the pilot initiative because it was considered relatively affordable, easy to use (according to the manual, it has an estimated battery life of up to eight months, which means the battery does not have to be charged often), and discreet (it resembles a wristwatch). Most importantly, however, the chosen device allowed participants to collect data on their everyday activity (mainly number of steps) and sleep (amount of sleep time), thus helping them record and make their daily activity and sleep routines visible, potentially helping them change these.

3.1 Key affordances and maintenance and repair of device

The installation and operating instruction manual of the chosen self-tracking device, Withings Activité Pop, emphasizes ease of use. The tracking of walking, running and swimming as well as sleep is said to be automatic, mainly only requiring the person to wear the device. As a result, the user can see their total number of steps taken during the day, the

percentage of their achieved daily step goal and the estimated calories burned during the day. After swimming, the user is informed of the length of the swim session and the calories burned. Regarding sleep, the user gains data on their total time spent sleeping and the duration of their light and deep sleep cycles as well as waking hours. The percentage of the daily sleep goal is also visible. The collected data are shown in the connected smartphone application (Withings Health Mate) in multiple ways: as graphs, numbers, and percentages and in different colours.

The manual has guidelines for both the maintenance of the device itself as well as the data flow it produces. For maintaining the functioning of the device, the manual tells the user what kind of materials to use for cleaning (e.g. lint-free cloth to clean the glass and casing) and how to clean the device (instructions for glass, casing and wristband). In addition, the manual has instructions for when and how to replace the batteries or the wristband of the device (when the hands have stopped moving and the watch no longer vibrates when the reset button is pressed).

The key issue of the production and maintenance of data flow is data synchronization. The installation and operating instruction manual promises that the synchronization of data continues in the background as long as the Bluetooth wireless technology is enabled. Automatic synchronization is triggered when the user has collected a certain number of steps, reached the daily steps objective, when enough time (over six hours) has passed since the last synchronization, or if the time zone changes or daylight saving begins (p. 29). However, the user also has the option of synchronizing their data manually: for this they must open the connected smartphone application and keep it close enough to the device itself. The importance of synchronizing data is emphasized in the following text, which is highlighted, bolded and marked with a warning sign: "Your Withings Activité™ Pop/Withings Activité™ can only store your data for 38 hours. Make sure you open the app regularly so that you do not lose any of your data" (p. 29). Updating the software of the device is considered an important part of its maintenance. The manual emphasizes the importance of data synchronization before updating the versions, as otherwise data might be lost.

The main advice regarding the repair of the device is that users should not try to repair or modify the device themselves and should leave this to a professional technician. If the user feels that the time displayed on the device is incorrect, the manual advises recalibrating the device. The manual provides no other instructions for the repair of data.

3.2 Methods

The participants received their activity wristwatches in February 2016. After approximately three months, they were asked about their experiences of using the self-tracking device and the data that it produced. The interviewees were selected on the basis of two criteria. First, whether they

had any previous experience of using a self-tracking device and second, whether they expected to learn to use the device easily or not. According to these two criteria, three different groups of participants were identified for this study. The inexperienced self-trackers had no previous experience of using any self-tracking devices, nor did they expect it to be easy to learn to use the device. The opposite applied to the experienced self-trackers. The extreme self-trackers were already using either two to three other self-tracking devices or had been using one device for at least two years and expected no difficulties in learning to use a new device. The underlying assumption regarding the identification and selection of the different types of participants was that the experiences of the inexperienced, experienced and extreme self-trackers would differ, and that the analysis would result in the identification of the different types of self-tracking routines that participants develop to improve their activity and sleep.

Twenty-seven out of approximately one hundred participants were interviewed in May and June 2016. Nine interviewees were inexperienced, nine experienced and nine extreme self-trackers (nine male, eighteen female). After roughly six to seven months, twenty-one of these agreed to the second interview at the end of the pilot study in December 2016 or January 2017 (eight male, thirteen female). The time period for both interview rounds was aligned with the schedule of the whole pilot initiative. The first round of interviews was held after three months of using the activity wristwatch, as the assumption was that by then the participants would have become acquainted with the device and that they would have developed some related self-tracking routines. It is important to note that the pilot participants were in principle committed to the use of the selected self-tracking device from when they received it to the end of the pilot study. As the second round of interviews took place at the end of the pilot study, it was possible to examine any changes in use routines.

All the interviewees were well educated. Eighteen had a university degree (from either a university or a university of applied sciences). One interviewee even had a doctoral degree. Seven interviewees had a vocational qualification and one interviewee had completed general upper secondary school. The age of the interviewees ranged from 28 to 57. All the participants gave their signed informed and voluntary consent for the pilot study. The shortest interview lasted 13 minutes in the first round and 9 minutes in the second round, whereas the longest was 80 minutes in the first round and 45 minutes in the second round. The interview questions had received ethical approval[2] and focused on the use of the self-tracking application (Withings Activité Pop) in the pilot initiative. More specifically, the participants were asked how they used the application, how they experienced the use of the application and whether they had any difficulties or problems when using it. They were also asked whether they used any other self-tracking devices, and if so, what their experiences of these applications were. All the interviews were recorded and later transcribed

verbatim, resulting in a total of approximately twenty-five hours of interview material. The anonymity of the interviewees was guaranteed throughout and after the interview process.

Careful reading and systematic coding (see Eriksson and Kovalainen 2008) of the interview material first revealed that not all, but many participants and all the types of self-trackers (inexperienced, experienced and extreme) had connectivity difficulties when encountering and trying to engage with their data. This means that some participants had problems with invisible or inaccurate data, which led to feelings of indifference. Therefore, the next step was to focus on how the participants attempted to deal with the difficulties they faced. This resulted in an analysis of the self-tracking routines that the participants talked about in their interviews. Their attempts to maintain the functioning of the self-tracking device and to produce a continuous, correct data flow were at the centre of their reflections.

4. Maintenance and Repair Routines in Self-tracking Context

The pilot study participants talked a great deal about their methods and attempts to follow their daily activity and sleep patterns through self-tracking. Interestingly, however, many of the self-tracking routines that the participants reflected upon in the interviews were related to the use of the self-tracking technology itself. They talked about the ways in which they tried to maintain and sometimes even fix the data flow showing either activity or sleep.

4.1 Wearing the device: rigid patterns and improvisations

The interviewed pilot participants were dedicated to self-tracking in the pilot initiative. The primary requirement for producing self-tracking data was wearing the device. The interviewees described how they wore their devices and checked the data that they produced on a regular basis. Many followed the number of steps they accumulated during the day and in the mornings checked their time spent sleeping as well as the duration of their light and deep sleep cycles at night. Many considered wearing the self-tracking device and the resulting data exciting and engaging, particularly at the beginning of the pilot initiative.

> Ten thousand [steps] is the goal. You can see at one glance where you are. If it starts to get late and it's about time to go to bed and I notice that I've not reached ten thousand [steps] it begins to worry me. Or, if I already know during the day that this is not a very active day, I may walk a longer route and take additional steps or something. It's become a positive incentive. (Female, 42, experienced self-tracker) (Interview: 1st round)

The excitement of the novel device did not necessarily last long. The routine wearing of the device was no longer motivating when the data stopped producing new learning insights or the device seemed to malfunction. The participant quoted above said in the second interview that after roughly six to eight months, wearing the activity wristwatch felt like having handcuffs. It was not easy to take it off.

> Before the battery change the watch kept time accurately. But it produced silly data as if I'd gone to bed at four, even though it was ten o'clock. Or it showed no data, even though I knew that I had run for seven kilometres.… This [malfunction] lasted roughly 1.5 months. I began to think I wouldn't be bothered if it couldn't be fixed. There was no novelty value for me anymore and as [the data] were a bit unreliable I started to think whether I should wear it at all. I would have liked to wear my own watch again. … I think that I gained the benefits of the device during the first six to eight months of use. I should perhaps try to better remember those insights and live accordingly even if I don't wear these handcuffs all the time. (Female, 42, experienced self-tracker) (Interview: 2nd round)

The same interviewee reflected on her dedication to wearing the self-tracking device in the course of the pilot project. She described her devotion to the routine wearing of the device as obsessive for a long time, even in situations when wearing it broke a dress code or it did not suit certain special festivities. She said that she no longer kept up the routine of wearing the device on all occasions.

> At the end of the summer, a friend of mine had a birthday party… As my hair and makeup were done, my hairdresser wondered whether I would wear the activity watch during the party. I told her that I collected data every day and that [people] won't notice the watch much under my lace gloves. Today, this would be out of the question. I would leave Withings lying on the table if I was invited [to a party like that]. (Female, 42, experienced self-tracker) (Interview: 2nd round)

Some of the participants who felt that the device did not register all the data that it should have were eager to experiment with different ways of wearing the device. These participants were particularly concerned about their activity data as they felt that the device seemed to register only some types of activity, particularly steps, and only when the circumstances for data registration were favourable, for example, when their hands were not still. The problem of lacking activity data mostly bothered the participants who were active cyclists, as the device did not register cycling at all, but also many participants who actively took part in different types of sports. Therefore, some of them tried to think of new ways of routinely wearing the device that would allow them to maintain a data flow of their activity that they considered more realistic.

I've had the Withings from the beginning [of the pilot study] and I use it and follow [the data]… We were instructed to wear it in our wrists all the time. But, let's say you cycle on an exercise bike for two hours. This means that you hold on to the handlebars for two hours and [the device] thinks that you've being lying on the sofa for two hours… Well, I did some tests and put it on my foot… It worked to some extent. It did recognize some activities. I noticed that in many cases it was better that I had it on my foot instead of my wrist. But, this isn't really the idea. (Male, 43, extreme self-tracker) (Interview: 1st round)

The above-quoted participant's dissatisfaction with the functionality of the device made him experiment with wearing the device in a way that it measured the different kinds of sports that he took part in more accurately, in a more versatile way. The experiment soon turned into routine use. Instead of wearing the device on his wrist, the participant wore it on his ankle.

Since the last meeting in the spring I've worn it as an ankle monitor. This is where it has least hindered my daily activities. But I quit using it as I didn't gain anything from it anymore… [This was] after the summer, sometime in the autumn. (Male, 43, extreme self-tracker) (Interview: 2nd round)

The participant quoted above felt that the device selected for the pilot participants was not designed for people like him who were active in sports. According to his experience, it did not recognize many of the activities that he conducted regularly, such as skiing. He also feared that it guided people to routinely do sports in an unbalanced way, as people wanted to demonstrate their activity through data, but the sensors measured only particular types of activities (mainly number of steps). The device was designed to be worn on the wrist, and although he felt that the device did not function properly when worn on the ankle, it collected data for him much more effectively than when he wore it on his wrist. Therefore, he kept the device on his ankle instead of his wrist until the watch strap of the device broke. This made him quit using the device completely, as he considered the data useless.

Another participant who was also extremely active in both sports and self-tracking tried to wear the pilot study device on her other wrist, as one wrist already held her own self-tracking device. This was because she feared potential connection disturbances between the devices. However, she felt that it did not help her collect accurate activity data.

The intensity of my workout in the gym, well, I was completely dead. It was terrible. there was no way I could have done anything else… Well, it showed that I had burned 127 calories and that was it. No calories burned! While my own device showed the recovery time [needs] to be at least 12 hours… I didn't wear [the two different devices] on the same arm because I thought that they [may] connect with each other and there

might even be interference or something. I wore the one on one hand and the other on the other hand. (Female, 52, extreme self-tracker) (Interview: 1st round)

The participant quoted above needed the self-tracking device most importantly to remind her of the importance of recovery time. Being motivated to be active and do sports was not a problem for her. Instead, she wanted the device to remind her that she also needed to remember to rest. The device used in the pilot study did not recognize all the sports activities that she did. This worried her and therefore, she tried to think of new ways to wear the device to help her collect data. She wore the device either on her ankle or on a different arm to her other self-tracking device. She was frustrated as she did not succeed in obtaining data that she could consider correct.

4.2 Tending to the device: automatic settings and manual tasks

Many participants mentioned that every day they routinely checked both the number of steps achieved during the day and the amount of sleep they got at night. Monitoring sleep seemed to be particularly interesting for most participants, many of whom were either in management or expert positions and suffering from high stress levels. Some participants mentioned having only four to five hours of sleep per night, which is well below the recommended eight hours of sleep. Obtaining and seeing the data required not only data collection but also regular data synchronization, either automatically or manually.

I wear the device practically all the time… It's easy in the sense that you just turn it on once a day. And, the phone reminds you to turn it on to synchronize the day's data… I do check the number of steps every day… I don't think I could do more in a day. My job, hobbies, and the hobbies of my children make it a 16-hour day. An evening walk after all that, no way! (Male, 40, inexperienced self-tracker) (Interview: 1st round)

Despite their stressful lives, many participants kept collecting, synchronizing and monitoring their activity (number of steps) and sleep data. However, being constantly reminded of goals that are hard to reach was trying.

I had it until around Christmas. But, I got bored somehow… I had a tough year. It didn't add to my well-being that the device told me I didn't sleep well. (Male, 40, inexperienced self-tracker) (Interview: 2nd round)

The participant quoted above held a high-level management position in a large organization. He used to do sport regularly but now found it difficult to find time for exercise. His heavy workload and stressful job left him sometimes only a couple of hours of sleep at night. The partici-

pant revealed that he had considered participation in the pilot study in order to slowly reactivate his sports routines. The result was, however, frustrating for him. He was only able to build up a routine of maintaining and monitoring a continuous data flow in his self-tracking device. He wore the device and synchronized the data devotedly every day. However, he claimed that seeing his constant failure to recreate the regular training routines he desired, or to increase his amount of daily sleep made him finally abandon the device completely.

Another participant compared the maintenance of the device to the care of a virtual pet, a Tamagotchi, which needs constant care and nurture. In the first interview round, the participant talked about her attempts to maintain a beautiful flower in the interface of her smartphone application. She emphasized the importance of caring for the four petals that represented her levels of activity, sleep, weight and blood pressure in proportion to the pre-defined optimal levels of these health and wellness areas.

> It has a visual incentive system containing all four different areas [activity, sleep, blood pressure and weight], so it's a bit like a Tamagotchi. You need to keep it happy… It turns into a beautiful flower when all these four areas are in balance. (Female, 39, experienced self-tracker) (Interview: 1st round)

Taking care of a pet, even if it is virtual, can be hard work that requires persistence. For the participant quoted above, taking care of her Tamagotchi meant not only taking enough steps or having enough sleep every day; she had also developed weight and pulse measurement routines, the results of which she needed to record manually.

> I'm clearly not as enthusiastic [as in the beginning]. I used to check [the number of] my steps every day, but now I haven't monitored them so actively. Instead, I've tracked my sleep every day. This is where I've had problems and therefore, it's been useful. It has increased my self-knowledge of my own sleep a lot. Monitoring sleep has clearly become a positive routine… My steps on the other hand, after my initial excitement I haven't walked as much [as in the beginning]. Then I've felt a bit bad, had a guilty conscience and been annoyed because I've cycled a lot but [the device] doesn't show cycling at all… I've [started] to think I might need a break from monitoring my steps, because there's no reason to feel guilty as I do exercise a lot. (Female, 39, experienced self-tracker) (Interview: 2nd round)

In the second interview, it became clear that keeping to the routines of caring for the Tamagotchi or maintaining the beautiful flower in the interface of the smartphone application had been too much work for the participant. She had given up measuring her weight and pulse as well as recording the resulting data of her device. She only followed her amount

of daily activity irregularly as cycling did not add to the numbers. Instead, she kept monitoring her sleep actively, as she had successfully overcome her sleep problems and had even been able to give up her sleep medication. The flawed numbers showing her activity, however, bothered her a great deal.

The users of the activity wristwatch were also able to share their data with others. Some participants in the pilot initiative who were colleagues at work teamed up to share their activity data (number of steps) and to compete in activity. Many of those who participated in this type of competition reported that it was motivating, fun or at least somehow stimulating.

> We can challenge each other. Now, [two of my co-workers] have challenged me. I can see their weekly [steps]. I happen to be in the lead now. For some reason, [the other co-worker] has not been able to update [her data]. That's why she has zero steps. I know she exercises a lot though. (Female, 48, inexperienced self-tracker) (1st interview)

The participant quoted above found the competition with her co-workers motivating. At the same time, she pondered the functionality of her own device and even that of her co-worker's device, as well as the visibility problems of the activity data. According to her, the problems with the functionality of her own device and the visibility of activity data continued and even increased in the course of the pilot initiative, which reduced her motivation to be more active in exercising.

> I'm not involved anymore because I always get so little steps. … Sometimes we talked during our coffee break about [who] had beat [the others]. I sometimes noticed that [a co-worker] had an evening walk around 11 pm and beat me. It was fun, but nobody talks about this anymore. … I wonder whether [one co-worker] has some problems too because I noticed a couple of weeks ago that that she only had 23 000 steps a week. In a whole week! She exercises outdoors a lot, goes hiking and does all kinds of things. How is it possible that she has only 23 000 steps? I don't believe it. Last week, zero steps. This week, zero steps. Most likely her device is acting up. At one point, she disappeared completely [from my screen]. I don't know what happened. She said that all her friends disappeared from her screen. (Female, 48, inexperienced self-tracker) (2nd interview)

The above-quoted participant quit the activity competition. She felt that some of her activity data remained unregistered and reflected on the possible causes of her device's functionality problems, such as the lack of memory space in her smartphone. She claimed that the problems continued despite switching her activity wristwatch for a new one and changing its batteries. It seems that the functionality of hers and her co-worker's device troubled her quite a lot and that she focused her attention on the technical issues of data recording.

4.3 Communicating with the device: Data synchronization and repair

Data synchronization was essential for the maintenance and visibility of continuous data flow in the connected smartphone application. Despite the operating instruction manual promising that the user "should never have to worry about syncing" (p. 29) their data, as this would take place in the background automatically as long as the Bluetooth wireless technology was enabled and when some specific milestones, such as a certain number of steps, were reached, some participants still had to synchronize their data manually. Data synchronization was thus not completely unproblematic for all the participants. Problems in data synchronization emerged when, for example, data were missing or data sets were broken. Some participants had developed peculiar routines for conducting manual data synchronization to ensure continuous data sets.

> I have a brand-new phone, but still, it doesn't always [synchronize the data]. You have to put the phone really close [to the activity wristwatch]… I don't know if it's because of the phone case or what… Sometimes there are days that show no activity, because I haven't remembered to put it right. Then you have to keep it [close to the activity wrist] for quite a long time before it starts importing [the data]… I usually try to do this once a day so that it begins to synchronize. Or, I put the watch on top [of my phone] and go and do something else… Otherwise it's easy to use, but if you don't always remember to hold your phone close enough to the [wrist] then it might not register [your data… It's all about routine, of course… but I don't always remember to do this in the morning. (Female, 49, experienced self-tracker) (Interview: 1st round)

The participant quoted above had a brand-new smartphone, but still felt that the phone did not always synchronize the data easily. Her attempt to solve the problem was to put the phone close enough to the activity wristwatch and let the synchronization take all the time that it needed. She had days that showed no activity (number of steps), and believed that this was because she had not remembered to position the activity wristwatch and the smartphone in the correct way for synchronization to take place. Although the operating instructions manual emphasized the importance of the activity wristwatch and the smartphone being close enough to each other while synchronizing data, the participant wondered whether the data synchronization problem may originate from her phone case. For her, data synchronization was burdensome. She stressed that remembering to synchronize the data required routines and thus tried to do it once a day in the morning. She did not always succeed, and sometimes forgot to do the manual synchronization, which resulted in missing data. As she felt that importing the data took a great deal of time, she sometimes just left the activity wristwatch on the top of her phone and

went to do something else. She left the self-tracking wristwatch to 'communicate' alone with the connected smartphone application.

It was important for the pilot participants that self-tracking produced continuous, visible data flows. This required them to ensure data synchronization and that the activity wristwatch 'communicated' correctly with the connected smartphone application. Some participants also brought up the issue of the reliability of data. For example, one of the pilot participants compared the data produced by the activity wristwatch with the data produced by a pedometer application, Moves, which could be uploaded for free onto his smartphone.

> Sometimes when I activate Moves, it shows some numbers. But, if I immediately restart Withings and then go back to Moves… it may add 1000-2000 steps. I don't know how it collects the data. From its own logs? Does it somehow spy on the logs in Withings? Is it a coincidence, depending on how I use it at specific times?… I haven't been able to figure out its logic. For example, why does it sometimes cut down my number of steps? Is it somehow connected to location information?… I don't know whether Withings works in the same way. Maybe it does, maybe it doesn't. I don't feel like synchronizing it so often because it's such a slow process. That's why I can't figure out if it works in the same way. (Male, 41, inexperienced self-tracker) (1st interview)

The participant quoted above said that he considered the activity data produced by the activity wristwatch more reliable than the data produced by the free pedometer application. At the same time, he felt that the data synchronization took too long in Withings and therefore, preferred to check the number of steps in Moves as it seemed to produce numbers in real time. He complained, however, that the free pedometer application sometimes either added or reduced his number of steps, which made him reflect on the possible causes for this. Uncertainty in the functioning of one piece of technology seemed to lead to concerns about the functioning of the activity wrist device.

Some participants in the pilot initiative felt that some of the data that the device registered were unreliable, even false, and tried to invent ways in which to guarantee accurate data that did not involve paying attention to wearing the activity wristwatch. Some participants were unsatisfied with the reliability of their activity data (number of steps), and others did not consider even the sleep data reliable.

> It annoys me that the device thinks I'm fast asleep even though I am 100% sure that I'm awake and watching television… Of course I don't move a lot when I watch television. I suppose if you don't move at all it considers that you're fast asleep… Every now and then I've tried to wave my hand like this in some direction so that it understands I'm awake. But, I don't feel like doing this all the time… It should be possible to correct [the data] myself. I could do this myself and [change the data] to show

that this is not sleep. (Female, 47, experienced self-tracker) (Interview: 1st round)

Inaccurate data may annoy self-trackers so much that they are prepared to do a great deal of additional work and invent routines that may seem odd to others, such as waving their hands to show the device that its owner is awake. The participant quoted above was persistent in her several attempts to develop self-tacking routines that would result in reliable data.

> I wear it on my wrist all the time, but I'm extremely disappointed because the numbers are so flawed. It gives way too few steps and it thinks that I keep sleeping all the time even although I'm just still… I've not figured out [how to fix it] because when I watch television, I don't feel like moving all the time… But I do see the times here. I can make comparisons and then I save my real sleep times in my [other smartphone app]. I check that ok, this is when I went to bed. I know that I watched the television for an hour. It may look like I woke up in the middle of the night but I know that this is when I went to bed from the sofa… I have tried to calibrate [=the different devices]. (Female, 47, experienced self-tracker) (Interview: 2nd round)

The participant quoted above was annoyed that the device interpreted that she was fast asleep even though she knew she had been awake and watching television. The participant came to the conclusion that the problem could be that she stayed too still while watching television. The inaccurate data annoyed her so much that she would even have been ready to correct the data afterwards through changing them manually from asleep to awake. Although this was not possible in the application, she tried to fix the problem by communicating with the device through waving her hands while watching television to tell the device that she was indeed awake. Waving her hands routinely or remembering to change her position constantly while watching television was, however, frustrating. Therefore, her next effort to obtain accurate data was to start using another smartphone application. She collected her sleep data via both devices, compared the data with each other, and modified the data to reflect how she remembered her sleep and waking hours. She recorded the corrected data in her new self-tracking application and thereby tried to calibrate the devices. We can conclude that she was ready to do a considerable amount of additional work in exchange for accurate data flow. One reason could be that she did shift work and had several animals at home to take care of and therefore wanted to make sure that she gained enough sleep every day.

5. Discussion

Self-tracking devices are considered examples of technological artefacts that offer possibilities for promoting lifestyle changes. This is because they help people collect personal data and thus invite them to develop everyday routines for monitoring, documenting and analysing various aspects of daily life that affect health and wellness, such as activity and sleep (e.g. Swan 2012). At best, the knowledge produced by self-tracking devices may result in the development of daily routines that foster and maintain people's healthy living and thereby also support the overall shift in health care from treatment to the prevention of diseases. Self-tracking technology can be considered an infrastructure which, due to its communicative affordances, allows people to create personalized, flexible routines as well as reflect upon them (Lomborg and Frandsen 2016). So far, however, an understanding of how people generate and interpret their self-tracking data, and how they incorporate it into their daily routines, has been lacking (Pink et al. 2017; Lupton et al. 2018). This study contributes to this critical stream of research through the empirical examination of reflections on the self-tracking routines of pilot participants in a large health and wellness pilot initiative.

In the studied pilot initiative, the promotion of individuals' lifestyle changes played an important role. Different types of health and lifestyle data were collected and returned to the pilot participants, who also received an activity wristwatch to collect their activity (mainly number of steps) and sleep data themselves. The underlying normative goal or the ostensive aspect of self-tracking in the pilot initiative was that the self-tracking device would not only allow the participants to document their data but also possibly inspire them to change their activity and sleep routines and thereby affect their health and wellness.

The results of this study emphasize the subjective interpretations and understandings of self-tracking device usage. Many of the interviewed pilot participants developed routines for monitoring and documenting their everyday activity and sleep data. In the evening, many of them checked the number of their daily steps, and in the morning they looked at how they had slept in the night. Some were even attracted by the elements of gamification or the possibility to use the self-tracking device as a toy or a tool for competing with others. Other participants mentioned that self-tracking data indeed acted as motivation to change their activity or sleep patterns. However, when reflecting on the data, many of the participants in this study did not mainly focus on how to produce better activity or sleep data, i.e. how to change daily routines to gain data that show an increased amount of daily activity or sleep. Instead, they primarily reflected on the routines that were related to the use of the technology itself. One of the reasons for this could be connectivity problems (Yli-Kauhaluoma and Pantzar 2018), when the data remained broken and were thus inaccurate or incomplete (see Pink et al. 2018). Therefore, they described

their attempts to create routines that would help them collect reliable da-
ta and synchronize the data between different technologies, i.e. the activi-
ty wristwatch and the smartphone application. For example, they experi-
mented with how to wear the device, on which wrist or even on their an-
kles. They applied elements of gamification while tending to the device.
They communicated with the device by, for instance, waving their hands
to tell the device they were not asleep. They organized time for data syn-
chronization to allow the smartphone application to connect with the de-
vice itself. They even tried to calibrate the device with their other self-
tracking applications. It seems that a close, even dialectical relationship
developed between the users of the self-tracking device and the technolo-
gy itself. Importantly, however, the practices that the participants devel-
oped did not necessarily have anything to do with the original aims of the
use of the self-tracking device in the pilot, i.e. the development of rou-
tines that improve activity or sleep thus contributing to health and well-
ness. Instead, in practice these routines emphasized the maintenance of
the digital flow of data.

The results of the study are based on a sample of pilot participant in-
terviews in two phases. The first round was held after approximately
three months of self-tracking (twenty-seven interviewees) and the second
round after roughly ten months of self-tracking in the pilot study (twenty-
one interviewees). Although the study protocol was strictly controlled and
focused on the use of the self-tracking device and the related service ap-
plication, the pilot participants gave rich descriptions of their technology
use routines. The advancement of individuals' lifestyle changes played an
important role in the studied pilot initiative. Therefore, it was surprising
that many of the participants' reflections mainly emphasized their every-
day tasks with the self-tracking technology instead of how the technology
had supported their activity and sleep routines or more generally, their
health and wellness. One reason could be that the interviews were not
conducted by a health or wellness professional, nurse, physician or per-
sonal trainer. Nevertheless, during the interviews, many participants were
eager to show their everyday activity (number of steps) and sleep data in
great detail. The need to reflect on routines for wearing, tending to and
communicating with the device might originate from frustration with the
'power of default' of technological artefacts, which makes their adapta-
tion and customization for better support of routines or routine change
difficult (see Koch 1999; Pollock and Cornford 2004; D'Adderio 2011).
This means that the deployment of novel artefacts that support particular
routines or even routine change is not easy.

The study shows that self-tracking requires users to do more than just
wear a device, as claimed by user manuals. Accomplishing self-tracking
routines calls for a great deal of effort (see Feldman et al. 2016) that in-
volves not only maintenance but sometimes even repairing the digital data
produced. This study shows that the maintenance and repair of digital
data are everyday tasks, not only for professionals involved with complex

data sets (Tanweer et al. 2016), but also for the ordinary people involved with different artefacts or consumer technologies such as self-tracking devices. The study suggests that the stability of routines is related to the meanings that technologies or artefacts produce, as well as to the affects that they have on their users. Among the pilot participants, the routines for maintaining the digital data flow often ceased if the users no longer found self-tracking data meaningful in their lives or when they constantly faced feelings such as boredom or frustration when confronting their personal data. As Ledger and McCaffrey (2014) have noted, self-tracking devices do not necessarily succeed in encouraging the long-term routine engagement their users. The constant maintenance work effort is not rewarding if it results in data that remain invisible, inaccurate, self-evident or frustrating.

6. Concluding Remarks

The study shows that self-tracking devices and the data that they produce may require continuous maintenance and even repair routines. Here, the device users had to exercise persistence, creativity, improvisation and even care in their attempts to produce complete data. The study suggests that users of self-tracking devices may develop even peculiar routines in their communication with self-tracking devices and data synchronization. Such routines may result in a close relationship between the user of the self-tracking device and the technology itself. The analysis of everyday routines thus helps expand the literature on self-tracking by revealing patterns in the users' application of their devices at specific times and places in their lives. More research on these everyday routines is needed to gain a better understanding of the spectrum of the invisible work of users, as device maintenance is often considered straightforward, and data synchronization, for instance, is regularly assumed to take place automatically or without much effort. Future research would be particularly valuable in cases when self-tracking devices or other novel technologies are introduced into people's everyday lives with the aim of helping them make changes to lifestyle routines that affect their health and wellness. The results could eventually contribute to the better design of technologies and more understanding of the type of additional support that people need when using such technologies in their everyday lives.

The study also suggests a need for more longitudinal research on routines and the related artefacts in general, and self-tracking routines in particular. The obvious challenge and premise of this study was long-term routine engagement with interesting technological artefacts such as self-tracking devices. Even the relatively small sample of interviews in two phases at six- to seven-month intervals revealed changes in people's reflections on their routine practices and the related affectual atmospheres. A focus on how changing patterns of action relate to changing affectual

atmospheres in self-tracking offers an interesting avenue for future research.

One important practical implication of the study concerns health and wellness interventions that are organized in the form of, for instance, pilot studies and trials. The study suggests that participants of such interventions are deeply dedicated to data production and their contribution to research: in this case, through self-tracking. However, the committed use of technologies such as self-tracking devices in organized health and wellness projects may simultaneously have unintended consequences. Constant recognition of failure to reach the desired activity or sleep data may lead to frustration rather than motivation in attempts to make lifestyle changes. Therefore, the design of pilot initiatives that apply novel artefacts for routine change and consolidation should caution users about the possible negative or unintended consequences of following routines and offer participants strong technological and social support.

Acknowledgements

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[1] The Digital Health Revolution (DHR) health and wellness pilot initiative was organized by the Institute for Molecular Medicine Finland (FIMM), HiLIFE, University of Helsinki.

[2] The DHR Pilot Study was conducted according to the guidelines of the Dec-laration of Helsinki. The study protocol was approved by the Coordinating Ethics Committee of the HUS Hospital District (51/13/03/00/15).

In Other Words: Writing Research as Ethico-onto-epistemic Practice

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Abstract: This paper aims to uncover the agential character of writing research in the light of the concept of ethico-onto-epistemology. Theoretically, it unpacks the debate around reflexivity and the performativity of theories and methods, underlining the active role of writing research accounts that do not just "capture" the world, but rather enact multiple worlds. This argument is developed with the support of empirical accounts belonging to an ethnographic study in a telecommunication company, which are informed by conceptual sensibilities from STS and Feminist Science Studies intended as two related yet distinct theoretical frameworks. I conclude by arguing that taking up the call for ethico-onto-epistemology when writing research accounts call us to trouble the character of writing as a neutral practice, and to grapple with the power of *accounting for* – thus producing – multiple realities that differ in terms of epistemological, ethical and political relations.

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1. Introduction

Science and Technology Studies (STS) have a strong history of accounting for the epistemic practices behind the production of technoscience as well as of reflecting on its own practices of knowledge production. The account for its own practices of knowledge production is a long-standing concern in STS since its origins, with the introduction of 'reflexivity' among the basic tenets of the Sociology of Scientific Knowledge (SSK) (Bloor 1991).

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The debate around reflexivity has been addressed from different perspectives – by pointing out that the patterns of explanation employed to account for technoscientific practices would have to be applicable to sociology itself (Bloor 1991), by stressing the issue of 'representation' and its practices (Woolgar 1988a; Lynch 1994), by describing the role of the STS researcher as 'the stranger' (Latour and Woolgar 1986; Shapin and Schaffer 1985), by advocating different configurations of knowledge expression (Bowker 2014) – and criticized within STS itself (Pinch 1993; Lynch 2000).

More recent approaches have stressed the performative character of social inquiry and methods (Law and Urry 2004), according to which research methods generate not only representations of reality, but also the realities those representations depict. This is not just a pure epistemological concern – i.e. assessing the conditions of STS knowledge production – as the principle of reflexivity outlined by Bloor (1991) points out, but a political one insofar as it urges to focus on the consequences and ontological implications of doing research and coming to know. It is not by chance that Annemarie Mol (1999) has phrased such understanding of theories and methods in terms of 'ontological multiplicity', namely the argument by which reality is done and enacted through specific material-semiotic practices rather than simply observed. Such and understanding of reality has been framed in terms of 'ontological politics' insofar as it calls into question the political character of social methods.

This interpretation of social research is close to what John Law (2009) has defined as 'interference', namely the act of making differences by means of descriptions and knowing practices. According to Law, feminist thinking has challenged the absence of radical politics in mainstream STS – such as SSK and Actor-Network Theory (ANT) – by showing the extent to which making knowledge means making difference, that is interfering with the object of the study. In this respect, feminist physicist Karen Barad argues that "'each of us' is part of the intra-active ongoing articulation of the world in its differential mattering" (Barad 2007, 381), pointing out that we make particular cuts through our methods and we need to acknowledge that these cuts are performative, and that other cuts are possible. This argument has important ontological and ethical implications which Barad has phrased through the concept of 'ethico-onto-epistemology', a compound word that appreciates the intertwining of ethics, knowing and becoming. What happens if we put Barad's call for ethico-onto-epistemology at work?

In this article I shall attend this question by focusing on the practice of writing research. More specifically, I shall provide and discuss empirical accounts drawn upon two years of ethnographic study in a telecommunication company. I will present four excerpts from ethnographic notes that I have written as informed by two related yet different conceptual sensibilities, STS and Feminist Science Studies[1], thus uncovering different ethnographic postures. A brief illustration of the debate around

reflexivity and the performativity of theories and research methods in STS precedes the empirical part along with a discussion regarding how the agential character of research writing constitute a fruitful research topic within this debate, with particular reference to the concept of 'ethico-onto-epistemology' (Barad 2007).

The contribution of the paper is twofold. On the one hand, I aim to unpack the debate around the performativity of theories and methods in the light of the practice of writing research; on the other hand, I shall bring the theoretical discussion into the empirical realm with examples of ethnographic accounts in order to argue for the importance of research writing as both knowledge-making and world-making practice.

2. From Reflexivity to Ethico-onto-epistemology: Feminist Science Studies Confront STS

Since their inception, STS grounded its intellectual roots into the critical commitment towards the constructive nature of technoscientific facts. One of the most significant threads that links the various strands of STS together is thus the acknowledgment that the production of technoscientific knowledge is a social and historical situated process. The principles of 'reflexivity', 'symmetry', 'impartiality' and 'causality' (Bloor 1991), set out by the so-called Strong Programme in SSK, have definitively stressed the importance of studying the very content of science as a social domain.

According to Bloor, being STS concerned with the account of the patterns of explanation which produce beliefs or states of knowledge (without any real differentiation between internal and external causes), that would also be the case for the accounts of technoscientific practices crafted by STS itself. The formulation of 'reflexivity' aims precisely to recognize such position as "an obvious requirement of principle because otherwise sociology would be a standing refutation of its own theories" (Bloor 1991, 7).

Since this first formulation, the concept of 'reflexivity' has triggered a sparkling debate within STS, with a number of different positions and perspectives[2]. Steve Woolgar (1988a), for example, articulates the distinction between 'introspection' and 'constitution reflexivity' by drawing insights on Harold Garfinkel's work. According to Woolgar, at the base of the discussion about reflexivity in and of sociological accounts of scientific work there is the problematic distinction between research methods and research object, an issue on which natural sciences and a large part of social sciences share the same view. As we shall see in the next section, the same concern about research methods and the conditions of textual production affects those ethnographic studies that set up the so-called 'linguistic turn' in anthropology (Marcus and Cushman 1982; Clifford and Marcus 1986).

Additionally, the debate around reflexivity problematizes the alleged detachment of the researcher from his/her field of inquiry, arguing that the presence of the researcher strongly affects the field where s/he is situated. This concern has been mentioned in notable STS works (e.g. Latour and Woolgar 1986; Shapin and Schaffer 1985) by describing the researcher playing the role of 'the stranger'. At the basis of such issues lies the relationship among researcher, subjects and objects of research, which, in turn, unveils different understandings of objectivity and knowledge production.

The situated and embodied character of knowledge production and the related critique of objectivity intended as the core mark and value of scientific authority have been deeply unpacked by feminist thinking. Perhaps the most popular text in this regard is the seminal essay by Donna Haraway (1988) on "situated knowledges" and the "privilege of partial perspective", in which, among other things, she introduces the figure of the "god-trick" to emphasize the pitfalls of both relativism and totalization, regarded as "twins" in the ideology of objectivity.

Against this backdrop, Feminist Science Studies (i.e. Harding 2011) take exception to the original formulation of reflexivity and impartiality as developed by the Strong Programme and social studies of science more in general, as they aim to mark out a reality that is not a premise of the representational nature of knowledge, but that is transformed through material-discursive practices. As Rouse (1996) points out, Feminist Science Studies have provided a more nuanced understanding of 'reflexivity' and its epistemic, rhetorical, and sociopolitical implications, arguing that knowledge is constructed as multidimensional relationships between knowers and knowns, rather than a simple relation of representation. This concern has also been phrased in term of "plain reflexivity" and "responsible reflexivity" as delivered by STS constructionist approaches and feminist epistemologies respectively (Lohan 2000). The equal consideration of epistemic and political issues as well as the concern to make knowledge more adequately accountable lead feminist scholars to conceive writing and speaking as forms of action that produce consequences on subjects and objects involved. Accordingly, in response to the notion of reflexivity as developed by constructionist approaches, Haraway (1997) counterpoises another optical metaphor – that of 'diffraction' – in order to underline the performative character of knowledge-making intended as world-making practices. Unlike reflection (and reflexivity), Feminist Science Studies (Haraway 1997; Barad 2007, 2003) have emphasized the mutual enactment of subjects and objects of research, moving beyond self-referential statements that, according to Haraway, resist to making strong knowledge claims and a difference in the world.

Barad (2007) borrows from Haraway the metaphor of diffraction in order to highlight the emergence of realities that are dependent on (more than) human activities and transformed through material-discursive practices. Unlike constructivist approaches, the focus here is not on the ways

whereby facts are constructed through rhetoric and inscription devices (Latour and Woolgar 1986) or on a reality that is "out there" and that the social scientist has to investigate without being in the action, finite and dirty (Haraway 1997, 36); rather, the ontology that Barad and Haraway point out is informed by the principle of responsibility, therefore it reminds to the "ontological politics" discussed by Mol (1999) insofar as it uncovers the ethical significance of research practices and the entanglement of epistemological, methodological and ethical issues typical of feminist critique. Here it is important to stress the fact that the notion of diffraction does not reject the notion of representation, but it invites to consider representations as performative in that they are constituted by meaning and matter, and have the power to interfere with the world's becoming (Timeto 2016).

The concept of 'ethico-onto-epistemology' developed by Barad serves precisely to argue that how we practice our research (epistemology) is constitutive of what becomes enacted as knowledge (ontology), and "therefore, we are not only responsible for the knowledge that we seek but, in part, for what exists" (Barad 1999, 7) (ethics). The value of bringing such a broad concern to bear on the specific practice of writing research lies in its capacity to uncover the agential and world-making power of the mundane practices – such as writing – informing the construction of knowledge. As Rouse puts it: "Observing, writing, and reading are not merely proposing or accepting the content of certain beliefs, but are themselves actions with consequences (one must consider to whom one writes, in what language, available to whom, drawing upon what patterns of interaction, using what narrative conventions and authorial stances, and who is permitted to respond, with what effects)" (Rouse 1996, 203). It is precisely such an understanding of writing – as a research practice that intersects epistemological, ontological, and ethical issues – that inform the four ethnographic postures presented in the following sections. (see section 4).

In what follows I will try to unpack the research question "what happens if we put Barad's call for ethico-onto-epistemology at work?" by discussing the practice of writing research, with particular reference to the concept of 'ethico-onto-epistemology'.

3. Ethico-onto-epistemology and the Practice of Writing Research

STS reflection on research methods has provided compelling reflections on the issue of research writing (Law 2004; Lury and Wakeford 2012).

Early concerns about research methods and the conditions of textual production affect those ethnographic studies that set up the so-called

'linguistic turn' in anthropology (Marcus and Cushman 1982; Clifford and Marcus 1986). These authors criticize the conventions of the realist genre that draws a clear line between the observer and the subject/object of research, so evident in the accounts provided by classical anthropologists such as Malinowski. In this case, 'the text is a neutral medium for conveying pre-existing facts about the world' (Woolgar 1988a, 28), such as the exotic characteristic of the subjects under scrutiny regarded as inner qualities rather than a symbolic construction. Moreover, the performative character of social research applies to writing as well according to Emerson *et al.* (2011), so that not only a writer's theoretical stance influences compositional choices, but the reverse also happens: writing styles reflect a theoretical orientation. Such mutual influence between theories and writing is differently articulated in the four ethnographic postures discussed in the following sections (par. 4.1, 4.2, 4.3, 4.4), which show how different epistemologies inform different modes of writing as much as different modes of writing resonate with specific theoretical sensibilities. The emphasis on the constructed character of ethnographic writings, conceived by postmodern anthropology as the product of the research rather than as a method (Marcus and Cushman 1982), leads us to envisage ethnographic accounts, as well as scientific work, as a matter of 'bricolage' (Lévi-Strauss 1962), a crafted product that makes visible some of the many realities at stake.

A similar spirit informs one of the most popular writing experiments in STS, that is Bruno Latour's book *Aramis, or the love of technology* (1996). It develops a hybrid literary genre called "scientifiction" as a result of the fusion of three distinct literary genres – the novel, the bureaucratic report, and the sociological commentary – in order to investigate the reasons behind the failure of Aramis, a project of a guided-transportation system carried out by RATP, the public transport authority for Paris. According to Latour, such a hybrid account, which is set up as a detective novel revolving around the mystery of "Who killed Aramis?", is meant to bring a technological object into the center of the narrative and to bring three different target audiences together: humanists, technologists, and social scientists.

Law (2004) takes a step forward in this debate by making a distinction between academic writing and novel writing. He argues that the distinction concerns means and ends, in that novels are ends in themselves and they make use of language as a world-making practice, whereas academic writings are means to other ends (namely a reality that is "out there" to be described and referred to). In observing how the writing of poetry and novels cannot be dissociated from what is being made, Law asks: "if we had to write our academic pieces as if they were poems, as if every word counted, how would we write differently?" and "how, then, might we imagine an academic way of writing that concerns itself with the quality of its own writing?" (Law 2004, 12). The understanding of writing provided by Law reflects a broader argument concerning the enactment of multiple

realities that the act of writing performs, and the consequent acknowledgement that writing, as a central feature of methods, is not innocent or purely referential. To rephrase Law (2004), writing does not 'report' on something that is already there. Instead, in one way or another, it makes things more or less different, and these different arrangements have political implications because they could be otherwise.

According to Law (2004), feminist writing (Haraway 1988, 1997; Mol 2002) has demonstrated the fluid, fractional, multiple, indefinite and active nature of realities, and, in doing so, it has showed how to write (label, name, classify) means to enact some realities and, accordingly, setting up a class-politics of ontology that the scientific system typically regards as objective and universal. In the case of the workplace ethnography presented in this paper, the political aspect of research writing (Marcus and Cushman 1982) lies in the challenge of making work practices visible from different positions, rather than providing a single-issue account from a supposed neutral stance (Suchman 1995). In this respect, Haraway (2013) has often recalled the impact of science fiction literature on her education and storytelling practice, arguing that writing and research are tightly coupled as they both require the factual, the fictional, and the fabulated. This claim seems to evoke Law's distinction between academic writing and fictional writing, and the call to imagine an academic way of writing that concerns itself with the quality of its own writing. STS ethnographer and poet Laura Watts (2009) have exemplified this blend of factual, fictional, and fabulated elements by elaborating two different stories based on the same ethnography of the mobile telecoms industry in order to enact two different methods: the first one is a reflective critique of the future in the industry, the second one is a generative and inventive interference. In doing so, Watts argues that storytelling is always a social, material and political practice, and that arguments and critical accounts are also a story with a particular literary form. Therefore, it matters what version of the story is told, being storytelling a means to construct knowledge, and being knowledge a situated construction of multidimensional relationships between knowers and knowns (Rouse 1996).

In the light of these reflections, in what follows I shall present four excerpts drawn upon fieldnotes written during an ethnographic research I conducted in an Italian telecommunication company for two years. I will begin by briefly describing the research setting and questions, the theoretical approaches that informed my research, and the performative role that such conceptual sensibilities play in shaping the writing.

4. Passic TV: Humans and Non-humans Between STS and Feminist Science Studies

Passic TV is an Italian company that delivers an on-demand streaming TV service within the broader business of Passic Mobile. Passic Mobile is a branch of Passic Network, an Italian ICT company which provides telephony services, mobile services, and DSL data services. Its headquarters are based in Rome and Milan, and it has many branch offices in several Italian cities. The company has several internal divisions, services and international partnerships.

The research I conducted in Passic TV focused on the work of a specific group – "the production team" as it is called within the organization – and the related development of a digital tool (a content management system) to support collaborative work. The design of this tool has uncovered not just technical concerns, but conflicts and tensions among different groups as well as the controversial role played by material artifacts in the process of organizing.

The ethnographic study – which comprised observations, interviews, attendance to meetings, informal conversations, and visits to the different offices of Passic TV located in Rome – unfolded over a span of 18 months, which I mostly spent by attending the work of the production team. At the time of the research, the groups consisted of 10 people with different roles (content editors, project, product, content traffic managers, and engineers). The work that the production team carries out is rather technical-based and consists of encoding contents (movies, TV series, documentaries, etc.), namely converting audiovisuals into different profiles according to the specificities of different devices (decoder, Android, Xbox and Apple) on which Passic TV runs.

During my participation at the first weekly meeting of the team, I identified two main organizational tasks involving the group: the development of an automatic encoding systems for contents and the design of a tool for workflow management. As I came to learn later in the fieldwork, these projects are interrelated as the tool, besides being a database of contents' information, was supposed to work in order to assemble the final product, namely to put the multimedia encoded and its editorial data together. Accordingly, the tool was later conceived to take over the human tasks of adding editorial data (e.g the title of the content, year, director, etc.) to the multimedia.

As the theoretical setup of my research was informed by the aim to explore the relationship between STS and Feminist Science Studies empirically, my ethnographic journey within Passic TV gave me the opportunity to focus on the role of the information infrastructure in shaping the cooperative work practices among different organizational groups. The analysis of the literature on Workplace Studies (Heath and Luff 2000; Suchman et al. 2002) and my first approach to the field have spurred the

following questions: what is the role of material artifacts in the process of organizing? What kind of and in what ways do feminist concerns emerge from the investigation of technology in organizations?

In attending such questions empirically, I increasingly realized the extent to which doing fieldwork with neighbouring, yet different, conceptual sensibilities poses different concerns and informs different ethnographic postures, thus enacting multiple and different realities (Mol 1999; Law and Urry 2004; Barad 2003). Such process of enactment inevitably involves the practice of research writing, being it the fundamental means through which delivering data, accounts, and the overall research experience.

The excerpts from fieldnotes presented below aim to pinpoint the heterogeneity of such research engagement as it has unfolded by following inputs and concepts from two conceptual approaches (STS and Feminist Science Studies), which affected both the type of content and the form of writing of the accounts.

The four excerpts presented here focus on the invisibility of the researcher as a "modest witness" (that is, according to Haraway, the androcentric stance that guarantees objectivity), the researcher as an active actor in the field, the "view from above", and the writing of passions. As we shall see, these issues materialize into different forms as result of different ethnographic postures, and, conversely, different styles of writing allow these distinct issues, as informed by distinct conceptual sensibilities, to materialize.

As the excerpts belong to the same ethnographic study, it is worth clarifying that they do not epitomize different literary genres; rather, they present different linguistic and discursive elements (e.g. passive verbs, personal pronouns, comparisons) that engender different ethnographic postures and forms of knowledge production and, accordingly, different realities that matter from an epistemological and ethical point of view. The excerpts are presented alternately, so that the first and the third ones are framed within a STS framework, whereas the second and the fourth ones are informed by Feminist Science Studies sensibilities.

4.1 Invisibility: the researcher as "modest witness"

The first excerpt refers to the early days of my ethnography in Passic TV, when I came to approach for the first time different places and people. These encounters prompted the writing of various accounts with descriptions of the internal and external appearance of the places that constituted the setting of the research, along with the routine actions that I learned to carry out in order to get access to Passic offices:

> The building in A street is very large, part of a larger whole. Even in this case it is a facility located at a bottom of a secondary street, not immediately visible from the main road. Unlike the

place in B street, the indoor environment appears bare, dark and sparsely populated: the building seems to be much larger compared to the number of people that actually contains. (Fieldnote)

> Upon my arrival at the Passic headquarters, I call Dario [project manager and my gatekeeper] as agreed and I wait for him outside the building. The structure looks very large, consisting of several blocks and several floors, even if it is located in a non-central and not very visible part of the city. The giant Passic logo that stands at the top of the building is in fact visible only after traveling several hundred meters from the entrance of A street (where the headquarters are located).
> To gain access to the offices, it is necessary to stop at the reception, register, release a document and tell the name of the person (a Passic employee) under whose responsibility the guest is admitted. After obtaining the guest badge, I pass the turnstiles and go to the auditorium, on the lower floor of the building, where the company meeting is about to start. (Fieldnote)

These notes contain a plain description of the human and material environments characterizing Passic TV. The writing stands on a denotative level, as it means to draw a direct and literal link between a signifier (e.g. "street") and its referent. The articulation of writing, therefore, is not meant to elicit particular meanings, allusions and feelings, even in the presence of qualifiers (e.g. "bare, dark and sparsely populated") that, in this case, are used according to a reporting style in order to collect data characterized by the lack of personal opinion and beliefs.

4.2 The researcher as an active actor in the field

These extracts from fieldnotes refer to my early interaction with the workers of the production team (first one) and to a particular event happened after the first year of the ethnography (second one). Both concern the theme of the researcher as active actor in the field, which have been explored in several ethnographic studies of organizations (i.e. Bruni, Gherardi and Poggio 2005). The first one accounts for what happened during my first interaction with Silvia (the coordinator of the production team at that time, then content and multimedia manager) when I asked her some preliminary information regarding the configuration of the technical infrastructure in Passic TV, which Silvia sketched on a sheet of paper.

> As I got to learn later on during the fieldwork, this sketch represents just a part of the whole technical system that supports contents processing and their release on the different devices. Rather, this visual representation became a matter of concern to me because, after that meeting, Viviana – who is the oldest member and the newcomer of the team – approached me asking if I could show

her the sheet of paper wherein Silvia sketched the technical system. Intrigued by such request, I asked her about the reasons of such a request. She answered that, as she was new to that group, she had not the chance to get a full picture of the organizational structure of Passic TV yet. (Fieldnote)

This note shows the set of unexpected events that an informal conversation can trigger. The question about the functioning of the technical infrastructure happened in fact right before the beginning of the weekly meeting involving the production team. Nevertheless, the detailed description of the technical infrastructure that Silvia sketched became a matter of concern (Latour 2008) as, through that, I came to learn about the peripheral participation (Lave and Wenger 1991) of Viviana (project manager), which I then decided to further explore by asking her an interview.
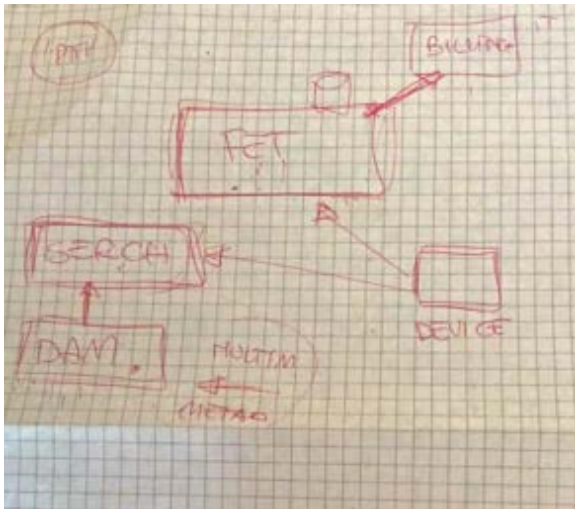
Figure 1. Sketch of technical infrastructure

If the note just described refers to my early days of research in Passic TV, the following extract accounts for a particular event happened after the first year of the ethnography, involving Carlo, the Web developer, who was initially managing the development of a content manage system.

At this point Carlo jumps into the conversation, asking for clarifications on the research I am doing in Passic. He is interested in knowing the real reason why I am there. The question is legitimate but unexpected, so I try to better understand. He tells me

that he would not be surprised if my work were also a consulting activity for the company, given the changes at the top in the last period. Carlo specifically asks me: "Is what you are doing here concerning your PhD project or is it connected to some other reason?". He does not have an inquisitorial tone, it seems to me he is more interested in clarifying his doubts.

I answer that my research in Passic only concerns my PhD, trying to use words and arguments that can support this statement. I explain again (I already interviewed Carlo as the developer of a computer-supported cooperative work platform, that they call "tool") that I am interested in understanding how the internal technical infrastructure works, following the development of the tool in particular. Carlo replies that even such an interest, together with the questions I asked him in the interview, concern the work dynamics and activities. I reiterate that my research concerns only my PhD as a way to reassure him, even if I do not think he needs reassurance. (Fieldnote)

A few weeks after this conversation with Carlo…

It's a long time since I don't see Carlo in the office. When we go for lunch at the canteen, I have the chance to talk with Silvia, who, during the weekly meeting, has hinted at the corporate restructuring and some changes at the top, and their impact on the work of the production team. Silvia also tells me that the developer of the tool has been replaced, there is a new person coming from a consulting company which, according to her, holds another approach to the work to be done on the tool, a better one than the one of Carlo according to Silvia.

This news reminds me to the last conversation I had with Carlo a few weeks ago. I remember his questions about the reason behind my work and my presence there, and, although I told him the truth, I cannot help think that he might have blamed my research work for the termination of his job at Passic. (Fieldnote)

These notes point out how the presence of the researcher in the organizational routine is not only a source of small incidents that make the observation substantially different from that of 'a fly on the wall' (Bruni, Gherardi and Poggio 2005), but it can also be controversial, if not painful. The recognition that the presence of the researcher – with her body, appearance, gestures, discourses and the interactions these may trigger – can be troubling as well as a source of unexpected events affecting other actors in the field suggests that the ethnographic account is not constructed as simple relation of representation and correspondence, but as a form of action producing consequences on subjects and objects involved (Lohan 2000).

4.3 The view from above: linear thinking and writing

The following two excerpts of fieldnotes concern that part of my research that was specifically devoted to the understanding of the overall functioning of the technical infrastructure as well as of the daily work of the production team. The first extract refers precisely to the troubles that an apparently simple operation, such as that of naming a file, can generate:

> If Ludovico [content editor] describes the operation of putting a name to file as an apparently naïve operation, in the words of Laura [service development manager] such convention of practice becomes problematic when the naming assigned by Ludovico and his colleagues does not coincide with the naming in the program schedule. (Fieldnote)

On the other hand, the following note reports a conversation I had with Carlo (Web Developer) regarding a new feature to be implemented into the tool:

> Carlo and I continue our conversation talking about updates on the development of the tool. What attracts my attention is a new feature that is being implemented on the tool. Carlo tells me about a script that one of their colleagues developed to improve the performance of the entire work chain, from the tool to the end-user. I think this information is interesting, so I ask Carlo to better explain me. Carlo tells me that it is a script that enables a function to search for content starting from data coming from Passic users' decoders. In this way, Carlo says, the control of quality over the content improves considerably since it will be even more rare to run into errors such as, for example, the failure to publish content (e.g. an episode of a television series). This technical innovation reminds me of one of the first conversations I had with Dario regarding the use of big data to improve the customer service. Actually, that conversation with Dario concerned the use of data generated by users for marketing purposes, but, in hindsight, I think what Carlo tells me has to do with the same issue, as the script they are developing builds on the data produced by the user experience on Passic devices. (Fieldnote)

If the notes in the previous section uncover a process of learning and writing that is embodied and mediated by the subjectivity of the researcher, these two fragments construct a mode of thinking as objective and detached, which follows a "logic of discovery" rather than a "power-charged social relation of conversation" (Haraway 1988). Here the researcher plays the role of 'the stranger' (Latour and Woolgar 1986; Shapin and Schaffer 1985) since she appears to be only interested in discovering the functioning of organizational processes, without any bodily

and emotional involvement. This posture results in a disembodied account because the researcher, although holding an active reflective stance, is interested in providing plain descriptions that do not problematize the relationship among researcher, subjects and objects of research.

4.4 Writing passions: the problem of access

The following account reports about one of the most popular issues concerning ethnography, that is the access into the field. It specifically concerns my first day of fieldwork and the consequences occurred after I incidentally arrived late to the scheduled appointment:

> Today, at 2 pm, there is an important meeting in which the chief of Passic Entertainment will be outlining major plans and objectives for the year in front of all the organizational groups. Given the importance and rarity of general meetings such as this one, Dario [my gatekeeper] has thought it could be a good way to start my research. The appointment is scheduled at 1:20 pm, 40 minutes before the meeting starts, since he has also arranged a brief introduction of myself and my work to two women executives: the chief of Passic TV and the chief of Passic Entertainment. I have been given some background information about them, so I am somewhat prepared for the day, yet I cannot help but feel a sense of uneasiness, because this is my first day of my first ethnography and I am about to approach two executives without having in mind a clear design of my study.
>
> Since the office is quite far from my house, I have checked the directions out so as to make sure to get to the place on time. According to Google Maps, the trip to Passic office will take around 45 minutes with the scooter. I then decide to leave quite early at 11:45 as in Rome it is likely to get lost in unfamiliar areas or, at least, that has been my experience so far. If I get lost – I think – I will have time to work it out and be on time.
>
> [...] After some kilometres, I decide to make a stop and check directions online: the road is quite large and there is no one to whom I can ask for information as I usually do. The place seems quite close to where I am. I look at the clock, it's 12:45: I can make it. I drive for further 5 minutes, but there is no sign of car dealerships and I have the sense of having gone too far. I'm getting nervous, I don't want to call Dario because I don't want he thinks I'm not able to arrive just by myself, but it's 1:10 pm and our appointment is at 1:20 pm, so I have to ask him. [...]
>
> When the appointed time comes, I am still on my scooter, finding the way to reach my field. I am more than annoyed. In years of job meetings, interviews, important appointments – I think – I have always arrived earlier. Today is the first day of field research of my PhD, I have to meet for the first time two people who are very influential for my work, and I'm late…

> I arrive eventually, around 1:40 pm, still in time for attending the meeting, but not for talking with the two women. I feel overtly embarrassed because I think that what has happened is a bad mark on my credibility and, above all, I feel ashamed for having put Dario, my gatekeeper, in a negative light with his bosses. (Fieldnote)

As Barbara Czarniawska notes (1998; 2004), the problem of physical access is well known in organization research and it has nothing to do with age or experience. It nonetheless points to a critical issue of organizing, that is 'logistics', which requires people and things to be in the right place at the right time. In reading the above fieldnote, I also acknowledge the feeling of vulnerability and fear of entering an "alien landscape" (Czarniawska 1998; 2004). This is all the more significant as, according to outstanding ethnographic examples (i.e. Reinharz and Davidman 1992), female researchers usually have an easier time than men in accessing mixed-gender field sites. As Czarniawska points out (1998; 2004), the fact that fieldwork is major threat to the identity of the researcher is not a very common topic in discussing field methods perhaps because the feeling of "being threatened" is at odds with the image of a mature adult and a competent professional. What I did not know at the time was that such feeling of uneasiness was not a methodological bug, but rather a field material and a source of knowledge, to become later an actual research strategy. In fact, shortly after the beginning of my ethnography in Passic TV, I have started to recognize that 'instability' and 'unpredictability' would have been two distinctive words by which to pattern my research experience. The ever-changing environment in which I worked allowed me to understand gaining access as a relational process (Feldman, Bell and Berger 2003) and a form of emotional labor (Blix and Wettergrenthat 2015), which that include self-representation, building and nurturing relationships as well as dealing with rejections, uncertainties and breakdowns.

5. Discussion: Writing Research as Ethico-onto-epistemic Practice

The extracts of fieldnotes presented in this paper invite to pay attention to the material and ontological implications of knowing practices (Mol 1999; Law and Urry 2004; Barad 2003, 2007). Being my overall research guided by the understanding of theories and methods as performative (Mol 1999; Law 2004; Law and Urry 2004), I sought to stay sensitive to such an understanding while conducting my ethnography; at the same time, such an approach to theories and methods as generative materialized during the ethnography in different postures as means to shed light on issues that otherwise would have remained invisible.

The excerpts presented and discussed account for typical issues in organizational ethnographies, such as the description of places and routines, the role of the technical infrastructure and the different degree of participation of actors in their communities of practices, and the problem of access. These have been thematized according to the conversation and tensions between the two related, yet distinct, conceptual sensibilities that inform the research (STS and Feminist Science Studies). As a result, they uncover different themes such as the researcher as a "modest witness", the researcher as an active actor in the field, the "view from above", and the disclosure of passions, which, in turn, take shape through different ethnographic postures and styles of writing that are an essential part of such conceptual setup. Indeed, the use of different linguistic and rhetoric tools such as passive verbs, personal pronouns, comparisons are not merely communicative instruments that convey a neutral content and meaning, but active practices that shape different forms of knowledge production that are not neutral as they matter from an ethico-epistemological point of view. Emerson, Fretz and Shaw (2011) captured the constructed and agential character of ethnographic fieldnotes with the expression "writing up" (rather than "writer down") insofar as "just as the ethnographer-as-observer participates with members in constructing a social reality, so too the ethnographer-as-writer creates the world through language". In doing so, I have tried to attend the call to imagine an academic way of writing that concerns itself with the quality of its own writing (Law 2004). As the ethnographic excerpts show, attending the quality of research writing means, in the first place, to interrogate the authorial stance that can craft knowledge in different forms, as either partial, finite and dirty (Haraway 1997) or as bearer of a supposed detached and neutral point of view.

Such an acknowledgement allows us to interrogate and value the character of our writing practices as a meaningful component of our theoretical and methodological apparatus in that they may (or may not) address and affect different audiences, with different consequences. In this respect, Brit Ross Winthereik and Helen Verran (2012) offer a compelling discussion of the crafting character of knowing practices, with a specific emphasis on ethnographic stories based on STS research cases. Drawing on feminist-informed notions, such as Strathern's 'partiality' and Haraway's 'double vision', the authors grapple with the question of how to write ethnographic stories and make generalizations upon them. The main assumption behind such concerns is an ethical one, that is the acknowledgement of the agential character of ethnographic stories, inasmuch as they are "*generative* for the people and practices that the stories are about" (Winthereik and Verran 2012, 37, emphasis in original). In mobilizing the notions of 'partiality' and 'double vision', the authors seek to call into question the dualism between a traditional academic perspective that regards research as non-interventionist and its opposite, namely the engaged and interventionist research. Against this background, partial

perspective and double vision suggest that the stories we write "are generative for *some of* the practices we study and for *some of* our own colleagues in social theory" (Winthereik and Verran 2012, 38, emphasis in original), and that other stories are possible. These insights resonate with Suchman's argument (1995) about the ambivalences of representational practices, with particular reference to work practices. In stressing the values of (workplace) ethnographies, she recalls Clifford and Marcus' "poetics and politics" (1986), arguing that we can begin to build representations that are aimed at working disparate knowledges together. In this respect, experimenting with research writing becomes a method whereby to address the challenge of making work practices visible from different positions, rather than claiming to provide descriptions from a supposed neutral stance. Accordingly, writing practices become examples of ethico-onto-epistemology "in situ" producing multiple realities that differ in terms of power, knowledge, gender relations, location and visibility.

6. Conclusion

In addressing the problem of how STS researchers make the objects of their research, Lucy Suchman (2011) argues that research methods constitute a practice, and that this practice is itself an object of research. In this paper, I have argued that this is a longstanding concern in STS since the elaboration of the concept of 'reflexivity' as one of the key pillars of science studies (Bloor 1976; Woolgar 1988a, 1988b; Ashmore 1989; Pollner 1991; Pinch 1993; Lynch 2000). However, I join Suchman's argument according to which Feminist Science Studies have shaped our thinking about this in a more radical way. She draws on Barad's elaboration in arguing that the sense of the *apparatus* extends "beyond the by now well accepted premise that instruments have material effects in the construction of scientific facts, to more deeply conjoin agencies of observation, including subjects, and their objects. She [Barad] emphasizes that we are neither outside of the world looking at it, nor are we inside of it. Rather we are of it" (Suchman 2011, 21-22).

Following this input, in this paper I have sought to shed light on the importance of writing research as a practice that contributes significantly to the "material entanglements that participate in (re)configuring the world" (Barad 2007, 91). This acknowledgement solicits STS researchers to trouble the character of writing as a neutral practice, and open up further questions that inevitably shape the form of our account: what and who is this written for? Whose voices and visions do it comprise? Who and what is left out? How could it be otherwise?

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[1] I use the phrase 'Feminist Science Studies' as in Barad (2011) to indicate a research and activitist field that questions the entanglements among matters of science, politics and power. To further clarify, as Barad puts it: "Feminist science studies was never a subfield of science studies that talked about women and gender. Feminist science studies, for all its diversity and because of all its diversity, is a richly inventive endeavor that is committed to making a better world" (Barad 2011, 9).

[2] To reconstruct the entire debate about reflexivity is out of the scope of this paper since this task would deserve an entire study on its own. To know more about the debate in STS, I would remind the reader to the following essential references: Woolgar (1988a, 1988b), Ashmore (1989), Pollner (1991), Pinch (1993), Lynch (2000).

Forming and Opening the Socio-spatial Logic of Constraint

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Abstract: While policy makers seek to realign socio-technical infrastructures and institutions based on the urgency of climate crisis and environmental degradation, civil society groups and community-based organizations enable ecologically informed practices every day. Focusing on the ways in which people interact with the local physical built and unbuilt environment, this theoretical paper explores the lingering social, spatial, and psychic implications of an anthropocentric logic of constraint that has dominated the design of institutions and spaces in the United States. Attention to the interactional dynamics of constraint reveals that even as institutions pave-over or displace vibrant social and ecological life there is an unevenness filled with cracks or openings that creates the conditions for socio-technical transition. Particular attention is given to the emerging people-plant interaction rituals, related to biophilic design or therapeutic gardens, that are enacted in-between conventional top-down and bottom-up processes. The potential of ritual interactions and collective consciousness in the design of plant environments is emphasized as a pathway to reconfiguring social-ecological relationships at multiple scales.

Keywords: social and environmental psychology; symbolic interaction; socio-technical transitions and practices; therapeutic horticulture and green care; biophilic design.

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1. Introduction

This paper explores the notion of constraint as it relates to socio-technical transitions and the practice-level dynamics of people-plant interactions. It overall seeks to understand how an underlying anthropocen-

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tric logic of constraint comes to permeate socio-spatial relationships – and how this logic is potentially, or partially, opened up in people-plant interactions.

In one sense, it may seem that constraints are imposed by economic calculations or operational management, and that constraints prevent transition from happening. For example, in the literature on a multi-level approach to socio-technical transitions, radical innovations are conventionally said to develop in "niche" level. Niches are "embedded" within the larger dominant socio-technical regime, and at the same time they are insulated from typical market forces in the current regime. In this portrayal of socio-technical systems, the logic of the dominant socio-technical regime constrains the ability for innovations to "break out of the niche level" (Geels 2002). Such language is especially relevant in "sustainability transitions," where the presumed necessity of economic growth has historically been at odds with environmental protection and green innovation (Smith, Voß and Grin 2010).

While there has been much focus on technical management possibilities and constraints for achieving sustainability goals, others (e.g., Shove and Walker 2007) suggest that there is need to focus on the "everyday politics" of transition management. With consideration of the everyday or practice-level, sustainability is no longer a purely technical achievement; it becomes about understanding the "shaping of subjectivities" (Avelino et al. 2016) or generating a "culture of care" (Gottschlich and Bellina 2017). Such conceptions of sustainability move beyond potentially simplistic notions of green cities, institutions or economies to understand the potential emotional, interpersonal, and affective openings for more environmentally sustainable societies – especially in terms of how humans experience and make meaning as part of vibrant ecological webs of life (e.g., Bennett 2010). More generally, notions of sustainability transitions also encourage consideration of how constraints in a socio-technical system can become disconnected from the wider constraints of living ecologies on Earth – through recognition of the accelerating extinctions and ecosystem collapses that threaten the very foundations of life.

The importance of different forms of constraint became especially evident as I began to study and practice therapeutic horticulture. I found that practitioners and researchers in emerging fields of therapeutic horticulture (cf., Straus and Simson 1998) and biophilic design (cf., Kellert et al. 2013) often focus on stories of transformation – at the personal, institutional, or community level. This focus on the transformative role of people-plant interactions is evident in stories of young children whose diagnosed mental limitations are overcome with people-plant interactions (Louv 2009), prisoners and correctional officers who find stress relief and new meaning in prison gardens (Jiler 2006), hospital patients whose healing is accelerated when exposed to plant environments and activities (Cooper-Marcus and Sachs 2014), urban community gardens that are used as sites of healing or urban activism (White 2011; Mares and Peña

2010), in addition to many other stories and settings of transformation (e.g., Sternberg 2010; Gallis 2013). Yet, much less is clear about how these emerging realizations, related to the transformative potential of people-plant interactions, might be connected to wider socio-technical transitions—that is, how interactional dynamics within sustainability niches could open up possibilities for transition to different forms of social organization.

In order to investigate the contributions that people-plant interactions might make to the emergence of sustainability niches for social-technical transition in highly urbanized and stratified societies, the paper proceeds in the following way.

First, it explores some of the implications of the dominant anthropocentric logic of constraint in the United States – where 20th century architectures constrained community and ecological interactions, and people were "sorted out" as they became secluded from each other and cut off from wider living ecologies (i.e., Fullilove 2013). It traces the ways that dominant socio-technical regimes form a socio-spatial logic that constrains bodies and lives. From an interactional and practice lens, constraint is conceptualized as an effect of economic or political calculation, which individual people or organizations may co-create, internalize, or push against. Attention is given to how constraint is related to the social-emotional qualities of spaces or institutions – for example, in the underestimation of human possibility, lurking melancholy, profound doubt, fearful withdrawal, or heightened suspicion.

Secondly, the paper explores how people-plant interactions can open up dominant human-centered logics of constraint. It theorizes about the ongoing design of people-plant interactions as a practice that can work from the inside-out to unfold new political capacities (i.e., Domínguez Rubio and Fogué 2017). This is not to argue that human connection to living plant ecologies creates a constraint-free environment, but rather that it potentially attunes social life to different ways of being together – perhaps more in alignment with inclusive, dynamic, reciprocal, or ecological constraints.

Finally, concluding insights are offered on how the intentional design and facilitation of people-plant interactions may be a key practice for socio-technical transitions. Although the focus in this paper is primarily on social and spatial processes in the United States, the emergence of people-plant interactions as transformative and therapeutic practice in Canada, Western Europe, Hong Kong, Japan, Australia or Korea (Haller, Kennedy and Capra 2019) indicates potential relevance for other contexts. Because nonhuman life uses forms of signification that are different from human signification, or even "more-than-human" (e.g., Kohn 2013), engagement with these practices requires attention to the ways people relate to society and space that are potentially behind, before, or beyond the dominant frames of social interaction.

2. Forming the Socio-spatial Logic of Constraint

Michel Callon (1998, 249) explains that "framing" and "overflowing" are inherent to economic and socio-technical systems. If framing is the process of establishing, "a boundary within which interactions – the significance and content of which are self-evident to the protagonists – take place more or less independently of their surrounding context," then overflowing includes the externalities that are not accounted for in the frame. Overall, Callon pays particular attention to externalities or overflows – in terms of how they are identified and measured in different disciplines or perspectives. From the more traditionally economic line of analysis, it may seem like "framing is the norm," and that "overflows are exceptions which must be contained and channeled with the help of appropriate investments" (Callon 1998, 250). Alternatively, the more constructivist approach sees framing as expensive, incomplete, and imperfect, which points to a need to identify where overflows are happening – or to understand the implications of certain frames, and how different frames might be developed.

In either case, elements of a socio-technical system such as a market or group of organizations does not exist as a finished product. As Callon (1998, 266) notes, the market "never ceases to emerge and reemerge in long and stormy negotiations". Yet when applied to a wider conception of socio-technical systems and transitions, it is also be important to consider the dispersed and uneven distribution of power, and the historical, spatial, or political context that shapes ongoing negotiations and production of socio-technical systems (Avelino et al. 2016).

One clear lingering consequence of an anthropocentric logic of constraint is the objectification and exploitation of both humans and nonhumans (Hodson 2003). In this, it is especially important to consider the emerging phenomenological or ontological turns in STS (e.g., Rod and Kera 2010; Jensen et al. 2017), which explore how socio-technical systems are related to the creation of new life-worlds and ways of being. Particularly in the United States, the calculative anthropocentric logic of constraint – that imagines places and entire groups of people as disposable, or in need of control and coercion – has had lingering implications for the worlds that people inhabit and create.

For example, Michel Foucault (1995) is known for his work on documenting the transition of punishment that occurred with the rise of modernity, from the punishment of body, to the coercive "disciplinary technologies," which use detailed classifications to govern human institutions and constrain behavior. In addition to the detailed record systems of modern institutions, Foucault also notes the spatial techniques for management or control that permeate society. While his analysis of Bentham's panopticon receives much attention, he also comments more generally on the cultural significance of emerging architectural and spatial forms that prison construction represented following the era of the Enlightenment:

> The whole problematic then develops: that of an architecture that is no longer built simply to be seen (as with the ostentation of palaces), or to observe the external space (cf. the geometry of fortresses), but to permit an internal, articulated and detailed control . . . in more general terms, an architecture that would operate to transform individuals: to act on those it shelters, to provide a hold on their conduct, to carry the effects of power right to them, to make it possible to know them, to alter them. (Foucault 1995, 172)

It is in this sense that the social and spatial organization of prisons is a lens that makes it possible to analyze industrialized and urbanized society more generally – especially the United States, which embarked on a massive prison building project at the end of the 20th century to incarcerate at the highest rate of any country in the world (Mauer 2006).

Sociologist Norman Johnston more specifically explores how this aspect of Foucault's theory is revealed in practice (Johnson 2000). Johnston traces what he calls the "administrative practice" of prisons – actual plans and built forms, goals of these forms, methods, policies, successes and failures. His central intent is to explore how the forms achieved the explicit and implicit logics that designers, architects, leaders, and the wider culture were constructing. For example, in the middle ages a duel system of courts, ecclesiastical and secular, led to different forms of constraint. Most notably, the ecclesiastical prisons held people for long periods of penitence that were meant to emotionally and physically coerce and control human bodies with orderly concrete and steel forms.

Figure 1: This 19th century historical drawing of Eastern State Penitentiary shows the early developing socio-spatial logic of constraint, where architecture is designed to change prisoner behavior through deliberate isolation, constraint, and seclusion. (Image Source: Wikimedia Commons)

In addition to being located at religious sites, and offering consistent views of an alter for those confined, these prisons set an architectural precedent of isolated cells where prisoners were constrained so that they would seek forgiveness for their behavior through penitence (Johnson 2000, 17-28). Here, architectural forms are quite literally considered as a strategy for managing or constraining human behavior. Overall, for Johnston the practice-level is especially important because it reveals the contradictions of purely top-down transition management. While social reformers of the 19th and 20th century imagined the prison as a technical solution to the "problem" of social disorder – a transition to a new kind of society with less violence and crime – they did not consider the potential long-term impacts that their form of socio-spatial constraint might have on daily interactional dynamics. Above all, this model of prison focused on isolating or removing individuals the living dynamics of social and ecological life, which has social and psychological effects that resonate within and beyond prison walls.

Loïc Wacquant builds on this in his analysis of the more contemporary implications of spatial and social forms of constraint in the twenty-first century beyond actual prison buildings – as he explores the ways that spatial confinement is a "technique for managing problem categories and territories" more broadly. Following the argument in his two books Urban Outcasts and Punishing the Poor, Wacquant develops matrix or continuum of socio-spatial seclusion that includes reservations, labor camps, prisons, ghettos, ethnic clusters, elite enclaves, and gated communities. These are forms of social closure and socio-spatial seclusion "whereby particular social categories and activities are corralled, hemmed in, and isolated in a reserved and restricted quadrant of physical and social space" (Wacquant 2009, 165). In this sense, socio-spatial forms of constraint are reflective of sociopolitical context and penal philosophy, and as Johnson, Foucault, and Wacquant suggest, the constructed forms take on a life of their own – as they constrain possibilities for social life. Moreover, the seclusion of poor and marginalized neighborhoods has also been connected to disproportionately high rates arrests and imprisonment in the United States, such that seclusion can be spatially mapped and observed (see Figure 2).

In the United States or institutions influenced by Western culture, this socio-spatial logic that focused on human-centered calculation and constraint permeated the 20th century more generally: hospitals where design and technology creates additional stresses for patients (Ulrich 2008); urban housing where "concrete machines for living" alienate residents (Blake 1977); schools where rows of students, isolated from the dynamic movement of the world, become passive containers to be filled with

knowledge (Freire 1968); offices that segment space in efficient linear order but reduce productivity (Oommen, Knowles and Zaho 2008); or prisons where extreme punishment and isolation can cause social and psychological harm (Söderlund and Newman 2017).
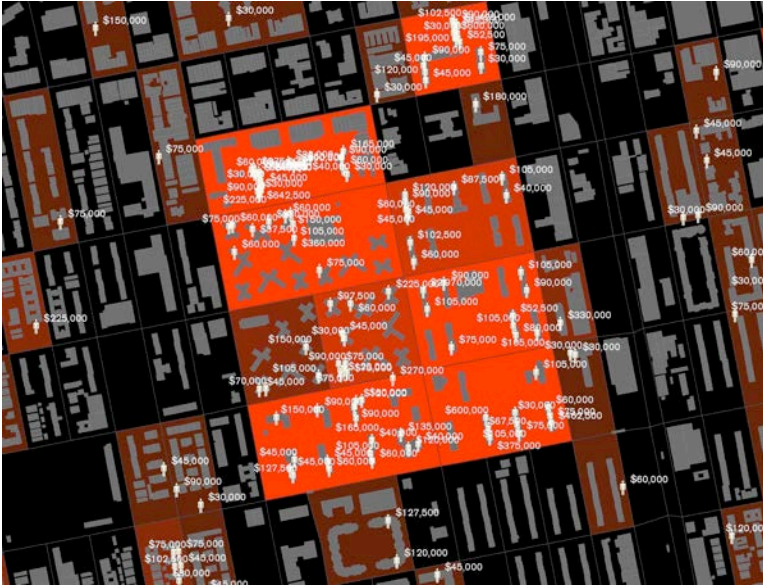
Figure 2: "Million Dollar Block" spatial analysis (Cadora et al. 2006) presents visual evidence of socio-spatial seclusion, showing each block in New York City where the State of New York spends more than one million dollars to imprison residents. Each human figure on the map represents where real person who is imprisoned used to live, and the dollar value represents how much the state is spending to imprison that person. (Image Source: Spatial Information Design Lab)

In this sense, an anthropocentric socio-spatial logic of constraint permeates the aesthetic and cultural foundations across many modern institutions, where people, things, and spaces are turned into objects. What can be constrained in human-centered forms of calculation and constraint is not simply the bodies of people or architectural forms; the creative capabilities of human activity are extinguished as living energetic matter is boxed-in or channeled towards fragmented systems of classification and instrumental rationality.
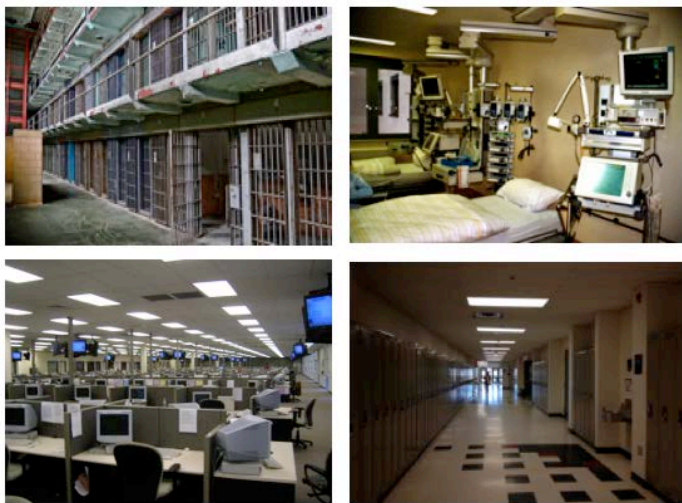
Figures 3-6: The architecture that dominated 20th century institutions (clockwise from bottom left: workplace, prison, hospital, school) prioritized efficient management of its subjects – where technological advancements often overshadow human life and the surrounding local environment. (Image source: Wikimedia Commons)

Overall, an implication of the dominant socio-spatial logic of constraint is that people are transformed into problems to be managed – the sick, the student, the prisoner, the mentally compromised, or the poor – through architectures, policies, and practices that have deep psychic implications. For example, W.E.B Du Bois (1903) became well-known for his writings about how racism is not merely about the misguided technical management of resources or intentional legal marginalization; but rather, for him, such forms of seclusion have profound psychic and interpersonal effects. He powerfully explores the question he was forced to grapple with wherever he went in the United States: how does it feel to be a problem?

Du Bois goes on to explain how the social scientists who were studying marginalized communities in the late 19th century approached people as problems to be documented in the name of social progress. Rather than seeking to understand people's everyday life and experience, according to Du Bois, these technical methods could contribute to a further social distance as they objectify people in order to fit them analytically into the dominant socio-spatial logic of constraint. An overall potential impact of this particular logic of constraint, which is still ongoing marginalized

communities today, is spatial anguish (i.e., Contreras 2017) whereby people may internalize a deep sense of shame, fear, or doubt about the possibilities for their personal and community life.

3. Openings for More Ecologically-Attuned Constraints

In the midst of human-centered calculative logics of constraint, it is also clear that people continue to creatively innovate in some contexts, as they inhabit what are could be considered "uninhabitable" conditions of social and ecological instability (Simone 2016). Accordingly, the dominant socio-technical regime may not create or allow niches of innovation; but rather innovations may be, "gradually and experimentally created out of discontent with, and in relation to, existing practices" (Hoffman and Lorber 2016, 692). This approach recognizes that the community or grassroots level is an important site of innovative activity in advancing sustainable development outcomes (e.g., Seyfang and Smith 2007). For example, research has shown that grassroots social innovations such as food localization can increase community capacity to address larger sustainability issues (Kirwan et al. 2013), or that people's "aesthetic experiences" in community gardens can create meanings that can lead to further engagements (Hale et al. 2011). This approach directs scholarly attention to the dynamics and interactions that might shape sustainability niches, with attention to power dynamics.

In particular, Gottschlich and Bellina (2017) explore how people's interactions with their local environment may be mediated by uneven distribution of environmental burdens and benefits. In order to open up existing systems and forms that perpetuate injustice, they suggest more attention to environmental justice and care work. While the environmental justice approach points to the need to look for practices and innovations in spaces or communities that have experienced marginalization or seclusion, care work brings attention to a need for transition studies to consider people and communities that directly care for the earth. Moreover, in environments that are mediated by powerful histories of seclusion and constraint, other scholars have pointed to the key importance of "performative connections." For example, Scotti and Minervini (2017) argue that sustainability transitions require multilevel and heterogeneous networks to connect on-the-ground practices with a larger effort for environmental governance.

Accordingly, spaces that reconnect people to each other, and to the local environment, may be important for social transition – especially in institutional or community spaces that have been neglected or abandoned under current or previous logics of constraint. It is in this sense that design can offer opportunities for opening an existing socio-spatial logic of constraint, and "unfolding" new social and political possibilities, as prac-

titioners on-the-ground rework previously designed socio-spatial relationships to include opportunities for different kinds of interactions and practices.

Domínguez Rubio and Fogué (2017) explain that although design is typically considered to be a process that "enfolds" the political, it can also have an "unfolding" capacity. Enfolding points to design's "ability to inscribe political programs into materials, spaces, or bodies" (Rubio and Fogué 2017, 97) – for example, as is evident in the aspirations of prison spaces that use architecture to manage and influence behavior under a political agenda of punishment and discipline. Conversely, unfolding operates as a "propositional mechanism" that points to alternative solutions, questions, and ways of being together. For example, collective community-based efforts to maintain a garden in an institutional space – or design opportunities for ongoing people-plant interactions – can bring people into relationship with each other, and wider plant ecologies, in new ways that may go beyond the prescribed or scripted uses of a space.

Although scripts are typically considered in terms of technological artifacts (i.e., Akrich 1992; Latour 1992), it is important to consider how plants may prescribe a different quality of interactions. In order to successfully grow plants, people need to relate to their environment in new ways. People-plant interactions require unique sensory and tactile engagements that are different from how people engage with more mechanically designed artifacts. The aliveness of plants invites different forms of reciprocity, care and reflection (Abram 1997).

This becomes especially important in spaces such as prisons and jails, where movements are carefully controlled and spaces are highly-scripted with strict demarcation of social roles (Goffman 1961). Accordingly, such institutions are perhaps places that best illustrate how people-plant interactions can begin to rework institutionally established frames, scripts or uses of space. I most powerfully noticed this in my own therapeutic horticulture practice.

For example, the first time that people arrive to a garden in a city jail in the United States, the most immediate reaction is often surprise. It's almost as if the aliveness of the garden allows visitors to see the constraint of taken-for-granted jail spaces surrounding the garden more clearly. There is a surprise from prisoners, officers, and visitors who are at the garden for the first time that "this kind of place" exists in a city jail. When they say "this kind of place," it seems that visitors refer to a certain kind of energy that exists – of uncertainty, openness, and possibility. What creates this kind of energy is a new socio-spatial logic and frame that accounts for plant ecologies. For example, different paths and sections of the garden that are being produced offer some sense of cognitive attention restoration (Kaplan, Kaplan and Ryan 1998) or relief from the highly regimented and ordered concrete and steel that typically constitutes prison environments. Moreover, these spatial forms are produced in the context of certain kinds of social relationships of learning, growth, struggle,

and transformation.

Similarly, community-based organizations or other activist and advocacy groups are co-creating plant-based environments to repurpose urban vacant land, which was previously scripted as "vacant" or in need of some kind of intensive capital investment (DelSesto 2015). These "insurgent spaces" can begin as activist projects and, over time, infuse spaces with memory or identity that leads to long-term community-led development or healing (Mares and Peña 2010; White 2011). Overall, such gardens can operate in contested spaces, and as sustainability niches, they are maintained or expanded through daily practices and interactions.

Repeated, daily and ritualized actions of civil society groups and voluntary organizations can produce social and spatial forms that are anchored in people-plant interactions – often from within spaces or institutions that are overwhelmed with layers of anthropocentric constraint (e.g., Straus and Simson 1998; Krasny and Tidball 2015). Although, ritual often has religious connotations, here it refers to repeated human interactions in the context of plants that has some sort of social meaning or intention.

The social space of gardens is based on shared directed attention towards different kinds of plants that may include: classroom lessons about horticultural topics, collective field observation where program participants can interact with the plant through sensory engagement (seeing, hearing, touching, smelling, or tasting), and activities that aim to produce plant-based products. Garden participants may learn to locate the lavender plant among the hundreds of plants on an expansive landscape, which will be soon be harvested and dried in the small greenhouse, for a lesson and activity about aroma therapy and the making of sachets.

When the lavender plant is flowering it might attract dozens of bees, buzzing with spectacular activity that fascinates many people, immersing them in the activity and sound. The oils generated by the plant linger on the flowers, and they create a powerful scent that can overpower other smells and is associated with relaxation. The ritual of harvesting the flowers requires a certain technique, so as to encourage the growth of future flowers and maintain the shape of the plant. It is in this way that plant environments invite focused psychic attention and bodily co-presence to facilitate the beginning of what Randall Collins (2004) refers to as a ritual interaction chain.

For Collins, social interactions are heuristics for larger structures and systems – in that observations of how people interact and exchange represent or point towards the ritual organization of society (Allen 2011, 101-135). Overall, Collins explains that society is made up of overlapping or multi-dimensional aggregations of interactions, where the situation rather than the individual is the starting point for understanding social life. In formulating his theory of the ritual interaction chain, Collins builds on a tradition of sociology with roots in Durkheim, Mauss, and Bataille that focuses on unconscious, psychic and symbolic aspects of social life (Pfohl 1998). Accordingly, the notion that symbols, unconscious patterns, every-

day practices, and emotional energy can have material consequences is central for understanding how ritual arranges and rearranges dominant modes of power – or provides the openings necessary for reconfiguring power relations.

The ritual interaction chain is especially relevant here as a theory of social-technical openings and transitions. For Collins, a top-down understanding of how change comes about is not the only explanation for how social change happens, and in some instances, it may fail to explain the processes through which society reconfigures. Instead, he argues that cultural forces such as symbolic objects and gestures, mutual focus of attention, and emotional energy may better explain social change, as they are where "the energy of movement and change, the glue of solidarity, and the conservatism of stasis" reside (Collins 2004, 3). It is important to note here that Collins places importance on energy – how it is harnessed, bound up, or transformed through human organization and ritual.

When horticultural practitioners write about the design of therapeutic or healing spaces, they similarly refer to the importance of the energy and rhythm of plant ecologies, especially as it can be experienced in the passage of days or seasons. For example, Rice (2006) explains the role of ceremony and ritual in horticultural therapy spaces and programs – explaining how activities can be purposefully designed to elicit and unfold collective rituals. Ceremonies with plants can teach people that, "life is a process rather than a series of activities that are judged by whether they bring us immediately to our goals," and ceremonies can help us to learn, "how to locate our human experience through metaphorical reflection and actual experience of our natural life cycle" (Rice 2016, 17-18). This may mean linking social goals and growth to plants, or working with groups to "cultivate images" that support a feeling of interconnectedness. Overall, it is evident that the social dynamics of ritual are quite important for plant-environments.

In Collins' formulation, the ritual begins in a moment of co-presence, where people come together to attentively engage with each other or the world (this is the beginning of the interaction), is an important opening where things can be in flux and social organization may be open to new possibilities. Co-presence is not necessarily a fresh start, as the history and power arrangement of previous interaction rituals are likely to influence how people come together, yet it would be impossible to explain away totality of the co-presence with words. Note that from the framework of ritual that Collins provides, interactions with people and plants need to be repeated, sometimes deliberately, to promote solidarity.

While simply being together in a location may not lead to new forms of social organization, moments of congregation can be a stimulant for social life at multiple scales (i.e. the coming together of previously separated energy fields in a way that could generate unknown collective energy) for social organizations and transformations. In addition to co-presence, Collins stipulates three ingredients for the interaction ritual to

gain momentum that include: mutual focus of attention, shared emotional mood, and barriers to outsiders.

These ingredients of the interaction ritual chain can be interpreted through the lens of people-plant interactions – or what might be considered people-plant interaction ritual chains. Such ritual chains unfold new possibilities, even from within the dominant socio-spatial logic of constraint, as they imagine previously unforeseen human possibilities inspired by the flux of living plant worlds. They also require that people learn to work with the unique qualities, movements, needs, and rhythms of particular plants and places.

The first element of mutual focus of attention, is a process at the center of interaction rituals (Collins 2004, 47-101). In this case, people-plant interactions will not serve to disrupt the dominant constraining logic of an institution or urban space if there is not some mutual focus of attention on specific plants, spaces, or environmental symbols. Here, environmental symbols are developed and transmitted as people interact in the context of plants to create shared meanings. Environmental symbols might include garden plantings or arrangements that are designed to invoke a certain feeling or state – such as labyrinths or wandering walking paths – or symbolic additions to a space that may include themed art, writings, or built landscape elements such as gazebo or reflecting pool. These symbols are especially powerful when they connect with group members personal experience and social location (e.g., Cermak 2012). The mutual focus of attention that such symbols can create is developed through discussion, workshop, or guided sensory engagement.

People may gradually come to take on shared moods about different design elements of a horticultural space. For example, Elizabeth Murray (1997) explores the archetypal elements of gardens that appeal to the five human senses. These include focal points that draw at attention through the creative use of paths and sight lines, strategic color-coordination, incorporation of flowing water, stone arrangements, and play with shadows and light. Moreover, these elements help to create many types of color, sound, plant, and flower vibrations. For example, Passion Flower vines are a common garden plant that can grow up to six meters tall with striking flowers that are up to ten centimeters wide. It has an unusual corona that is composed of hundreds of delicate filaments radiating out around the star-like center. On a warm summer afternoon, the flower can be seen opening in a matter of minutes, with the petals vibrating as they dramatically unfurl.

Another ingredient for interaction ritual chains is a shared emotional mood. Here, there needs to be some kind of reckoning with the varying experiences and situations that people may bring to a garden space. This can take the form of group check-ins or a group conversational space (e.g. using therapeutic techniques to promote openness and dialog) that could allow space for people to bring how they are feeling in the moment they arrive to a garden space. In other words, there needs to be some oppor-

tunity in the garden for the possibility of what Collins (2004, 66-67) calls "conversational turn taking." Such conversational turn taking may start off slow and scattered, and slowly pick up pace or fall into a rhythmic entrainment.

Figure 7 and 8: On the left, a passion flower opens. On the right, therapeutic garden design at a hospital in the United States engages patients and staff in healing through its accessible design and incorporation of symbols. (Image sources: Wikimedia Commons and Legacy Health)

Figure 9: A well-designed and programmed garden space can create spaces for group congregation and conversation, shared activities and learning, or individual observations and activities. (Image source: Wikimedia Commons)

A final ingredient is a barrier to outsiders. In the case of people plant interaction rituals, the barrier to outsiders may involve a sense of ownership. For example, people may invest time, energy, and money in growing and caring for plants. There are many contexts where space may be limited, and the inclusion of some people means the exclusion of others. In community garden settings, plots may be assigned to individual people, or in institutional settings a certain organization may be responsible for designing and managing a space. There is also the potential for people who share a space or a particular landscape of plants to protect it from new members who may not have the same knowledge of how to care for plants. In other institutional cases, people may work with plants in the context of an already-closed institution, which limits the degree of inclusivity possible.

Overall, this ingredient is a reminder that even in addressing anthropocentric forms of constraint, some new kind of barrier will need to be assembled in a way that promotes inclusion of new groups and ecologies. For example, plant environments can allow for different degrees of participation – from passive observation to active engagement and long-term cultivation. While bright colors can attract a passerby, it may take some time to fully include a newcomer to all of the collective meanings and practices of a space.

This new barrier could also be considered as a move toward more ecological forms of constraint, with an openness to people and plants that have been previously ignored. From within anthropocentric constraints, it may appear that many life forms are expending themselves uselessly (Bataille 1988, 19-44), like the cherry tree that "uselessly" drops its abundant blossoms (Braungart and McDonough 2002). Yet it is precisely in paying attention to the seemingly useless actions and qualities of plants, that more life sustaining constraints may emerge. In other words, sustained people-plant interaction rituals can nourish qualities of being that, "reject prior calculation of returns as a defining feature of exchange" (Emerson 1976, 341). Note that this orientation towards more ecological constraints does not reject calculation entirely, but rather rejects forms of "prior" human calculation in order to nourish an orientation toward learning, openness, curiosity, or justice – in people and organizations (e.g., Senge 1990; White 2018).

While the dominant socio-spatial logic of constraint tends to ignore the living realities of plant ecologies, the more ecological constraints associated with the practice of people-plant interactions may open up possibilities for new ways of relating to the Earth. In contrast to the development of industrial capitalism, which is said to be characterized by the "domination of nature" (Leiss 1994), people-plant interactions can encourage alternative approaches to a wider ecology that may be referred to as the "wooing of the earth" (Dubos 1980). As Dubos explains, the environmentalist approach of the 20th century typically argued that socio-technical transitions toward a more environmentally-aware society would

require humans to withdraw from their interactions with the environment, because of the damage that society can cause. Yet Dubos advocated the need to learn from the wider ecological constraints of living plant worlds—that may have a logic outside of calculative instrumental rationality – in order to work with nonhuman systems from a place of respect and imagination.

4. People-plant Interactions and Socio-Technical Transition

There is a great significance in considering the dimensions of people-plant interactions in the context of social-technical transitions. An overemphasis on anthropocentric "prior calculation" has been a defining feature of capitalist industrial development, and this emphasis often ignores interactional dynamics in space, including how inner life shapes the social world. This is to say that the reorganization of society might need to be prefigured by or in tandem with a "reorganization of self" (Macy and Molly 1998) – not as a technical achievement, but as part of an experiential process or "ecology of participation" (Chilvers and Longhurst 2016) in which people need to actively engage.

Policies and architecture can change to promote some vision of sustainability, but how do people actually experience the built and unbuilt environment? When practitioners transform constrained institutions or neglected spaces into intentional sites of repeated people-plant interactions, they are creating conditions for the reorganization of self and society. It is in this sense that the design of people-plant interactions may be a case of how people may re-write given social or spatial scripts (cf., Akrich and Latour 1992) to reflect more ecologically attuned social relations and organization from the practice level.

It is important to note that promising possibilities of people-plant interactions are not a universal outcome of practice-based transition toward a more sustainable life and society. In many ways, plants have historically been part of urbanized societies—for example in the top-down planning of urban parks and recreational spaces. What is new is the intention of practitioners to cultivate healing or therapeutic spaces that are meant to lead to personal, organizational, or community change in settings such as schools, prisons, hospitals, or neighborhoods. In an era where concerns about planetary and human health are increasingly connected, analysis here suggests that it will be increasingly important to consider how interactional dynamics of people-plant interactions can be facilitated in ways that create lasting impacts for personal, institutional and societal transformations.

Overall, an attention towards people-plant interaction ritual chains shifts the focus of people-plant interactions from top-down technical management to presence, which is simultaneously oriented towards an attentive mindfulness of micro-level needs and relaxed awareness of mac-

ro-level conditions. Such an orientation seeks to value the variation and difference that might emerge in situations. Healing garden spaces, with their boundless variety of people-plant interactions, are therefore potentially well-suited to be oriented towards an "interdependence of mutual (non-dominant) difference" (Lordre 1983). This difference can be initially recognized, acknowledged, and welcomed through the senses.

Overall, this paper has explored the ways that, the dynamics of people-plant interactions may illuminate important, previously unconsidered, pathways to socio-technical transition through more ecological forms of constraint. It is long been noted that 20th century institutions and spaces are characterized by widespread sensory deprivation that can constrain social and psychological capacities (cf., Berman 1990; Louv 2009). Accordingly, people-plant interactions may orient social life toward qualities of previously unconsidered plant ecologies through practices, rituals, and a sensory re-orientation that includes the living more-than-human world. It is this way that people-plant interaction rituals might open up new ways for people and organizations to see, act, or be.

The result of this re-orientation is not that people abandon all forms of constraint or discerning judgement; but rather, practices and rituals within plant environments may facilitate a shift – from the linear rhythms of calculative instrumental rationality toward the more cyclical or reciprocal rhythms of the plant world. The opening, or unfolding, potential of people-plant interactions is therefore neither prescriptive nor certain. As an important emerging practice that may contribute to socio-technical transitions, the phenomenon of people-plant interactions calls for further investigation about how socio-spatial interventions can use plants to enable new ways of organizing social life as part of a wider ecological community.

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Connecting Dots: Multiple Perspectives on Socio-technical Transition and Social Practices

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Abstract:. This Crossing Boundary hosts contributions accounting for experiences and theoretical perspectives which may look distant for how they address the socio-technical transition in the energy field but, we believe, when put in conversation, help common questions and tentative answers come to the fore. Giorgio Osti, Paul Upham, Paula Maria Bögel and Paula Castro have been engaged in reflecting on their respective disciplines in relation to socio-technical transitions. Recalling and valorising the STS basis of MLP and SPT in connection with other disciplinary approaches may contribute to enrich on one side STS debates and on the other empirical research on socio-technical transition in a historical juncture where such an endeavour looks definitely urgent.

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Introducing Some Dots

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Climate marches have come again to the forefront as expression of environmental movements. The issue of climate change is global and so are social mobilizations and actions that further stress the seriousness of the threat (e.g., Climate Networks and Fridays for Future strikes). To contain the effects of human influence on climate and the environment, mobilizations urge institutions at national and international level to act more effectively. Among the many actions required, a global energy transition from finite fossil-based to renewable zero-carbon systems is probably the most compelling and challenging. The toughest point is that fossil fuels contribute dramatically to climate-impacting emissions yet, besides being the dominant kind of energy source, are still an economically convenient energy source (Kerr 2010). Hence, far from entailing a univocal technological substitution, energy transition involves an encompassing reconfiguration of society, arguably implying a different social order. For instance, transition requires a shift from a rigid approach based on centralized governance and large-scale energy plants to a more flexible one based on distributed governance and small-scale energy production to increase efficiency and improve management of energy demand (Smil 2005, 2019; Sovacool 2016; Sarrica, Brondi and Cottone 2016). The pathway towards a different energy regime is undoubtedly a crucial ecological issue, since it can reduce the carbon footprint and limit detrimental mining and extracting activities; yet, it also implies significant political, economic, social and cultural shifts. Beside entailing a relevant geo-political shake-up, such a re-configuration is multi-layered (Geels et al. 2017), as it includes both technical innovations and changes in social practices, organizational life, markets, civil society and a variety of policies and institutions.

In the search for a more sustainable society and less climate impacting forms of energy production, distribution and consumption, the social sciences have contributed with relevant theoretical debates and empirical studies. Several comprehensive conceptual frameworks have been proposed to understand the multifaceted nature of the transition processes (Araujo 2014). Two important ones are the multi-level perspective (MLP) for the study of socio-technical transitions and social practice theory (SPT). Both these approaches build significantly on STS. Compared with other issues, however, the STS community has shown so far lesser interest in this theme, also when studying techno-scientific innovation. On the contrary, research from other disciplines, for example sociology of the environment, anthropology, geography, political sciences and social psychology, has produced valuable outcomes. Yet, studying the socio-technical transition towards de-carbonization can hardly ignore an STS point of view (Sovacool 2014). Such considerations led us to elicit reflections that can be useful to an STS readership. This Crossing Boundaries

section aims, so to say, to connect (some) social science dots – hence its title. More precisely, the following contributions present experiences and theoretical perspectives coming from different scholarships, which may look distant for their epistemological standpoints and ontological premises yet, we believe, if put in conversation, may highlight common questions and tentative answers. Namely, against the backdrop of the urgency and political relevance of assessing strengths and limits of a variety of moves toward an energy transition, we promoted an interdisciplinary dialogue between environmental sociology (thanks to the contribution of Giorgio Osti) and social psychology (thanks to the contribution of Paula Maria Bögel, Paul Upham, and Paula Castro). Of course, this is a restricted choice, in no way corresponding to the claim that these disciplines are the most relevant to studying this topic. We regard instead this Crossing Boundaries section as a conversation that has to continue and broaden. Valorising the STS grounds of MLP and SPT, on the other hand, may contribute to enrich both STS theoretical debates and empirical research. In this spirit, we asked the invited authors to reflect on the way their respective disciplines address socio-technical transitions.

As developed by Geels (2002), on the basis of a first formulation of Rip and Kemp (1998), MLP approaches socio-technical transition by distinguishing analytically three social levels, corresponding to different spatial and organisational scales, from micro to macro, and provided with different degrees of stability, which account for how socio-technical innovation trajectories develop: i) niches, sufficiently protected from socio-technical pressures, where innovation can spring out; ii) established socio-technical practices based on norms, institutions and material infrastructures, which constitute relatively stable regimes, and with which innovation has to engage if it is not to remain confined in niches; iii) an "exogenous socio-technical landscape" consisting of a set of heterogeneous factors (Geels 2011). Landscapes include external conditions such as environmental constraints, as well as normative and cultural norms. These constitute the most durable and hard-to-change context of socio-technical regimes (Geels 2002). Beside evolutionary economics and neo-institutionalism, MLP builds on the Dutch tradition of social studies of science and technology; consistently with its origins, it has been applied to understanding socio-technical transitions, looking at these from a co-evolutionary outlook. MLP has been applied to account for individual mobility, the trajectory toward steamships and the development of airplanes engines (Geels 2005). It has been successfully applied as well to the energy sector, for studying the transition towards sustainability. Moreover, it is recognized as a valuable framework for policy-oriented research (Hargreaves, Longhurst and Seyfang 2013). SPT, at least in the guise promoted by Shove, Pantzar and Walker (2012)[1], conceives of practices as a unit of analysis. A practice is to be distinguished from single actions, as it consists in a nexus of repeated actions and social life arrangements. So, practices exist only in relation with others and emerge as such

when their components – skills or abilities, technologies and artefacts, and symbolic meanings – are connected (Shove and Walker 2007). SPT is popular among scholars engaged in a variety of fields (Hui, Schatzki and Shove 2017), yet, as noted by Warde (2014), sustainable consumption is a research topic which not only is dominant but has led to theoretical developments whose relevance extends well beyond this particular issue. Such version of SPT is micro-oriented, addressing how social dynamics are reproduced and can be disrupted through new arrangements emerging between material elements, such as technological artefacts, skills required to use them and the symbolic value they bring with them (Hargreaves 2011).

In spite of some connections, MLP and SPT are considered as competing outlooks (Hargreaves, Longhurst and Seyfang 2013), since their basic approach differs. MLP privileges a vertical perspective that moves upstream from niches of innovation to broader changes. In this regard, it aims to reply to criticisms addressed to STS prevailing micro-focus on socio-technical change, for its failure in providing an encompassing picture to the benefit of an analysis of relatively closed, local contexts (Geels 2002, p. 1259). However, MLP ostensibly meets with some limitations. For example, it has been criticized for its insufficient consideration of the role of materiality, of the dispersed and uneven distribution of agency and power, and of the importance of the historical, spatial and political context (Avelino et al. 2016). Other criticisms stress that the assumption that innovation follows a vertical trajectory leads to an excessive focus on institutions. Furthermore, MLP typical work on secondary analyses of official data may represent a methodological weakness. By connecting these criticisms with sustainability issues, moreover, inconsistencies and ambivalences emerge, especially regarding the renewable energy sector. Brand new regimes do not always fulfil their promises at local level (Scotti and Minervini 2016); conversely, niches do not necessarily promote a detachment from existing regimes (see e.g. Schreuer 2016).

SPT, in its turn, looks mainly at the horizontal circulation of different components of human activities (Shove 2012). As a result, a critique, mainly coming from MLP scholars, is that studies of practices are "highly contextual, and often developed in response to local problems" (Geels 2019, p. 7). Consequently, SPT analyses of sustainability transition do not take particular care of the different scales at which local processes take place, concentrating chiefly on everyday life (Welch and Yates 2018).

Attempts at integrating between MLP and SPT have been already proposed for instance, at a theoretical level, by Geels (2011) and Raven (2012). Others have re-analysed MLP case studies adopting an SPT outlook and vice versa (Hargreaves, Longhurst and Seyfang 2013). The take-home-message, here, is to refuse ontological partisanship. Indeed, researchers may profit from considering both vertical and horizontal trajectories of innovation, as favouring one does not necessarily entails neglecting the other. Taking these elements together, one can see additional

room for discussion, not only concerning the scale on which to focus, but also what to look at and what type of processes one is aiming to disclose. Through this Crossing Boundary section, we aim to expand these issues in interdisciplinary terms, according to an STS sensitivity for socio-material connections. We refer to the role of non-human agents, from infrastructures to devices for energy consumption monitoring. These have a crucial relevance both because of the path dependency they contribute to generate, as Osti's paper stresses, and because "delegation" to new technological tools implies social control. Osti elaborates on the opportunity of merging social sciences with the hard sciences that deal with energy issues; apart from the already mentioned role of material elements, he looks at the study of social practices as instrumental to enhancing the significance of the social relations implied in the energy transition. A risk in studying these questions he underscores is of plunging into renewed forms of determinism. It is easy, and sometimes convenient in analytical terms, to depict the individual as a purely rational actor; indeed, there is plenty of literature devoted to how behaviour can be oriented through scripts inscribed in technical objects and their arrangement in social spaces (see for example the "nudge" approach: Thaler and Sunstein 2008). Along this way, however, one falls into a well-known technological reductionism.

Social psychology can contribute to overcoming rationalistic perspectives as well: in particular, cognitive and behavioural approaches have provided useful insights in this direction. However, such approaches suffer from being focused on individual-level issues (e.g. attitudes, emotions, motives). The contribution of Upham, Bögel and Castro highlights lines for further development in the understanding of the subjective experience of individual actors and groups imbricated in the energy transition processes. Their point concerns the need to achieve a more comprehensive understanding of the individual-society link. A more co-generative vision of social changes lies in social representations and identity theories. In particular, these theories may complement the SPT approach, since they focus on psychosocial processes, going beyond the individual level, and fostering the vision of individuals as agents of transition rather than passive recipients. Moreover, an integrated reading of these different theoretical approaches allows for a better comprehension of the role of the material world and its components as well as their appropriateness in everyday life.

There are several open questions, which the papers contribute to highlight: for instance, how to apply a flexible approach instead of aiming at a grand theory. The study of practices, in this sense, is promising; however, it is seldom used for comparative studies. As the next sociotechnical transition is likely to be first of all centered on energy, future research on this subject looks definitely urgent.

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Above, Beside, Under: Three Ways Social Technical Disciplines Can Work Together in the Energy Transition

Giorgio Osti[2]

Introduction

Experts with different backgrounds often face together inextricable energy issues concerning pollution, geopolitical unbalances, and conflicts with local populations. They broadly agree on the necessity to adopt a multidimensional approach (Freunek Müller et al. 2015), but they rarely discuss how knowledge is developed and shared.

Thus, it is useful to elaborate some points for a reciprocal contribution between social sciences - more specifically sociology - and disciplines that have direct involvement with energy management. The latter are usually specialisations of engineering (Goldblatt et al. 2012). In this essay, they will be identified for convenience as technical disciplines.

The aim of this paper is to frame the relationship between social and technical knowledges of energy transition. The temptation of reductionism is strong, even for disciplines, such as spatial sociology, that consider themselves systemic (Rutherford and Coutard 2014). We will neither ar-

rive at a unique methodological approach, nor at a 'recalibration of various scientific hierarchies' (Asdal and Marres 2014, p. 2056). The relationships between social and technical disciplines are and have to remain 'plural'. The dream of a grand theory including any kind of knowledge has to move forward.

The paper deals with three ways social sciences and techno-sciences match in the attempt to enact environmental change (Asdal and Marres 2014). The reciprocal position of social sciences and techno-science will be illustrated with three spatial metaphors: above, beside (or in between), and under. Distinct attention is given to some perspectives included in this Crossing Boundaries section: spatial forms, material actors, and social practices. The last one is probably the key for representing the energy transition in a more relational way, overcoming the limits of both holistic and atomistic analyses. This sentence will be qualified thanks to further middle-range categories proposed here, namely monitoring, sharing, playing with energy: their application will be the final result of the paper.

Above, Beside, Under: Three Ways Social and Technical disciplines Can Stay Together

A broad justification for dealing with relationships between disciplines in a plural way comes from the observation of widespread phenomena related to energy issues. We often note that the latter are framed according to geopolitical schemes; they are a vital resource for winning wars and assuring the economic development of countries (Tidwell and Smith 2015). The role of energy sources for national security is indeed essential; thus, their exploitation has to be put as a dependent factor of other, more powerful processes. Socio-political disciplines then deal with specific knowledges about energy extraction, distribution, and use from a more general standpoint. We may call it the 'above' position.

A less widespread position can be called the 'beside' or 'in-between' one. Immediately after the launch of public schemes for subsidies, renewable energy sources (RES) became an industrial sector, growing in the market but necessarily cultivating connections with public policies and institutions. Indeed, any new electric device needs public authorisation. For this reason, energy transition raised a great number of interest groups pressing authorities for permission and support. In this case, the socio-political sciences are beside or in between the technical ones.

The third outlook social sciences offer to techno-sciences in relation to energy issues can be called 'below' position. It is exemplified by the great support socio-psychological disciplines provide to economic choices of consumers. The individual demand of energy is only apparently linked to natural needs of comfort. It is instead filtered by comparisons with other consumers and a variety of ergonomics that take the name of home automation (*domotica* in Italian). In this case, the social sciences provide information useful for adapting technical devices to consumers' tastes.

The 'above' perspective is endorsed by relevant scholarships. To mention a few of them we can include: i) The cognitive frames that are relevant for accounting for the embeddedness and social epistemology (Yasunori, Walsh 2010) of energy transition (Osti 2012). ii) Political ecology which provides a robust framework in order to locate struggles for energy within a more general conflict of capitalism with actors opposing its tendency to expropriation and exploitation of land and labour (Sovacool 2016). iii) Energy as first mover of society: indeed, there was a moment in the history of sociology when energy was considered as an essential component of social functioning (Carrosio 2014). Ecological approaches based on resources and population can be inserted as well in this vision of energy.

To give a further example of the 'above' approach, we can use two controversial Dutch cases, one project concerning shale gas extraction and the second about the capture of CO_2 as studied by Pesch et al. (2018). The authors identify three types of justice claims concerning both the projects — distributive, procedural, and based on recognition — and two types of trajectories for their assessment:
- overflowing (formal trajectory embedded in the legal system)
- backflowing (informal trajectory mainly embedded in public discourse and grassroots mobilisation).

The claim based on the struggle for recognition of local public resistance (that entails dignity, respect, identity, etc.) is the most neglected, but it is of high efficacy for both an understanding of the events and the capacity to mobilise people. According to Pesch and colleagues (2018), there is an ongoing and fertile passage between formal and informal types of assessment, whose effect is the scaling up of controversies toward the national level (see other cases in Pellizzoni 2011). In fact, after these conflicts, the government has changed the procedure for environmental assessment of large-scale works (Pesch et al 2018, p. 831).

A connection between the already mentioned frame-based approaches and those based on political ecology is further noteworthy. For example, Franklin and Osborne (2017) adopted the same typology of justice claims. But they used it for ideological reasons. They argued that the argument about the financial burden of photovoltaic panels, since their installation is not affordable for poorer households, serves the private local utility to cover its own interests for fossil sources of energy. In this sense, the Marxist concept of ideology makes this technical procedure comprehensible within a larger framework. Even though they offer a consistent perspective, these 'above' approaches present some limitations. Both political ecology and cognitive sociology make holistic claims, but they neglect the power of relationships (see debate in Wagenaar and Bartels 2016). These can modify both the recognition process (it is possible that a participatory process itself raises the issue of local identity and dignity) and the relations of production. For example, utility workers, usually the weaker side in labour relations, become stronger in the negotiation and

press the managers to leave dominant fossil sources. A well-organised association of consumers can counteract and change the terms of energy trade. Usually, the 'above' frameworks are rigid, conceiving material interests or cultural values as immovable data. The application of iterative approaches, primarily by scholars, can modify these fixities, giving more agency not only to weaker social parts (e.g., the local population) but also to manufactures and infrastructures' management. Micro-wind turbines are generally more acceptable than big ones. If local people oppose giant wind farms, the energy company may opt for introducing smaller turbines (which have their own logic of action).

The 'beside' approach needs a brief introduction. It deals with the position of the social sciences in between advanced technical systems. The basic idea is the existence of organisational fields developing through sets of institutionalised rules (neo-institutionalism of DiMaggio and Powell 1991; on energy issue, Fuchs and Hinderer 2014). However, such fields do not depend passively on external general systems as previous approach does. Rather they multiply, specialise, and equip themselves with some sort of self-government, self-learning, and self-celebration (Lidskog and Sundqvist 2018).

All these 'selves' provide good and cost-effective functioning, but they raise the need for professional transactions with other systems. Rarely is an energy system completely self-sufficient. Bad or rarefied relationships with other systems cause a lot of problems (transaction costs). Thus, communication systems have to be created in between. To think this can happen automatically or only thanks to the installation of sophisticated ICTs is an illusion. The fulfilment of so-called energy sector *unbundbling*, which should be able to break the old monopolies, requires new companies specialised in human and social communication. Of course, these intermediate actors adopt other ICTs; see, for example, the electric market, which works like the stock exchange.

MLP, also called 'theory of transition', is frequently used in the energy sector. It can be considered exemplary of the need for social 'bridges' between separated institutionalised fields. Geels (2010) portrays the real world as a set of fields – landscape, regime, and niches – with different levels of organisation, recognition and, finally, closure to external forces. Change happens when a specific project aligns one system with another, creating a socio-technical innovation. In this kind of approaches, the simplest case is the alignement of innovation niche to socio-technical regime (Schot and Geels 2008).

A famous retrospective research is the transition from horse-drawn carriages to automobiles (Geels 2005). Geels (2005) shows that several socio-political systems intersect with the rise of modern mobility systems, in particular, new consumer tastes and windows of opportunity for normative change. His approach is fully socio-technical. Automobiles are thus not only an efficient way to move, but also a means that allows the interaction of four specific social needs: the need for personalised

transport in terms of destination and privacy (avoiding contact with other passengers); the need for moving outside the city for recreation (picnic); the need for organising new racing fields; and the need for connecting people living in suburbs or on farms. These niches coalesce in favour of small autonomous means of locomotion, whereas an *omnibus* – a collective means of transport – clearly does not match with the individualised needs for spatial mobility.

Geels (2005) recognises there is no perfect alignment of fields, showing that the multilevel pattern works also in deviant cases. He notes a long co-existence between horse-drawn carriage and automobile regimes. In general, we think of simple substitution, but sometimes transfer prevails: the company making carriages starts installing engines in them. Intermediate systems emerge in between the niche and the regime; thus, electric trams were working for a long period after private automobile affirmation and today they know a renaissance.

Ultimately, MLP, even if more flexible than holistic or 'above' models, still follows a sort of *ecological and institutional functionalism.* Indeed, such a model proposes a population ecology of organisations that are mutually interdependent and variably recognised by institutions (Hannan and Freeman 1977). In this regard, interdependency is based on mutual satisfaction, while public recognition happens because of adaptation to rules, principles, or customs.

The double contingency of relational approaches (Donati 2010) and the idea of role distance typical of dramaturgic allegory (Goffman 1961) provide a fruitful terrain for critique. In MLP, actors are almost absent; we talk of population according to ecological models. Thus, agency is neglected, including the possibility of a range of reactions from actants, such as material objects, and socio-technical configurations (Walker and Cass 2007). In the study on private car diffusion, it is easy to imagine a socio-technical system formed by a driver and his/her own car, almost indistinguishable from one another. Yet, the diffusion of the self-driving car is bound to change the balance of agency between driver and means of transport in favour of the latter. The actant's perspective thus becomes more relevant, shifting the attention to algorithms and those who elaborate them.

Relational approaches can be declined in terms of reciprocity (Göbel et al. 2013). In that case, MLP appears even more distant, as one may wonder whether an actant – imagine not only a self-driving car, but also an automatic system for regulating a hydropower plant – may be able to use the register of reciprocity. Modern hydropower plants have a system for recharging the basin with the water below. The plant is regulated by the principle of best price/least cost of working, because of the mentioned introduction of an electric market. In theory, such a plant could be regulated by a mix of principles, including the need for water by downstream farmers, conservation of a minimum flow, and beauties of an artificial basin full of water. At this stage, a relevant question might be if and

how the software, managing the hydropower plant, will be able to also regulate relationships of reciprocity between different uses of water.

Looking at those objects through such a perspective introduces us to the third way social sciences and techno-sciences interact: that is, by locating the former below the latter. Basically, social scientists receive requests and instructions from engineers. To make some examples, managers of energy utilities often ask to survey their consumers or employers to determine the level of satisfaction with the services provided. Similarly, managers ask experts of communication to inform residents nearby a power plant or open a dialogue with them about forthcoming major investments for its enlargement; indeed, there is an extensive literature on methods of participation (Chilvers and Kearnes 2015).

On the other hand, behavioural sciences such as psychology provide the best example of the 'below' position, because they tend to accept without discussing the aim of the organisation that commissions a research (Kasperbauer 2017). The main example comes from the 'nudge' approach, in which a light system of incentives pushes people to adopt behaviours more coherent with the goals of saving energy and, consequently, money (Thaler and Sunstein 2014). Venier and Palmieri (2018), managers of an important Italian utility (Gruppo Hera), show in a very practical way the usefulness of the nudge approach. They have two premises:

> i. Pro environmental policies have to be plural, contemplating bonding rules, material incentives, and a wide range of measures based on moral suasion. Most nudge techniques fall within the last category;
>
> ii. It is easier and more convenient to change people's behaviours than machines. People are more flexible than industrial devices, which also have a high cost of initial investment. On the contrary, users can be 'convinced' with simple methods, changing the architecture of the system. Heating modularisation of spaces is a typical example: rather than changing all the heaters, it is easy to digitalise the system and make people aware of their levels of consumption.

The second premise by Venier and Palmieri (2018) shows an unexpected resistance to change by non-human actors. Mechanical devices built at a big scale and highly integrated show more resistance than modular settings made of small devices only partially connected. Smart grids in the energy sector imply the use of sophisticated software quite close to artificial intelligence. Thus, the crucial point is how modular units of energy production and consumption interact and whether they are considered as actants or socio-technical devices.

Before getting to a conclusion on this important aspect, we come back to the basic information provided by the nudge approach applied to energy saving. Venier and Palmieri (2018) confirm the approach of Thaler and Sunstein (2014): information supply on levels of consumptions above the average induces energy savings. People are more averse to losing money than being rewarded; thus, they are more committed towards en-

ergy saving than winning a prize as the best consumer. On the other hand, according to Venier and Palmieri (2018), this strategy is not exempted from unwanted outcomes; indeed, most virtuous consumers may tend to consume more, the so-called rebound effect (see Greening et al. 2000).

Hera managers, however, point out that psychological behaviourism works more for households than for firms. Indeed, material incentives for firms are still necessary for inducing energy saving. The reasons are again psychological but, in this case, they are internal to the organisation. First, factory managers are concentrated on the core business, which unlikely is energy saving for the sake of the environment; second, the savings achieved with energy saving measures are not necessarily included in a scheme for assessing managers' performance. As a result, it is likely that managers activate on energy only if they see great gain for company, such as major material incentives arriving from outside. Otherwise, they prefer to contract out any energy service, like saving interventions and maintenance of energy devices. In other words, managers are not motivated to compete with managers of other firms on the field of energy.

Behavioural psychology seems to work better for households than for factories. Thus, the 'below' position of social sciences needs both internal integration between different kinds of psychologies, and vertical integration with other approaches, at least history and sociology, placed in the 'above' and 'beside' positions. The architecture of energy saving needs – according to Hera managers' conclusion – extensive knowledge of each factory, its employers, and its physical structure for planning ad hoc interventions, discussed with all stakeholders. Otherwise, it is preferable to externalise the energy service, losing sovereignty and increasing transaction costs.

In conclusion, psychological mechanisms have their own strength, but they have to be supported by i) analyses of the socio-cultural context (e.g., in mainly Protestant countries the value of competition is more accepted, than in non-Protestant ones: see Hayward and Kemmelmeier 2007, p. 392); ii) understanding of the professional ethics of managers and employers, who can prefer the option 'to buy' the energy service than 'to make' it internally; and iii) the study of the geography of reference groups: near businesses rarely work as 'benchmarks' for readjusting a company behaviour. Finally, relational dynamics have to be considered, because the nudge approach is based on a cognitive comparison, not on material exchanges among actors. This last criticism introduces the attempt to make a combination of varied social science positions vis-à-vis the techno-sciences. This attempt relies on the study of social practices.

Social practices in Search of a Model

The social practice approach (SPA) has been extensively used in environmental and energy sociology (Bartiaux et al. 2014). The reason appears clear looking at the limits of behavioural approaches. SPA allows considering simultaneously agency, space, and time — in other terms, actions, environments, and durability. Because a large part of human activity is routine with little variation, it appeared clear that neither single acts nor contexts in isolation have to be studied but long sequences of situated interactions (Shove 2017). Thus, energy saving behaviour is neither a simple reaction to a stimulus (your neighbour is better than you) nor the result of just a reflection in the actor's mind, as some cognitive approaches affirm; nor, finally, the sediment of prolonged interactions, as social constructivists hold. It is a practice in which cultures, spaces, and habits co-exist, forming appropriate 'atmospheres' (Löw 2008).

Practices of energy saving thus become a sequence of small daily gestures, made up of control of the temperature in the room, calculated openness of windows, adequate clothing, and so on. They are effective as long as they are under the control of actors (agency) and affordable, without great investments in infrastructures. Moreover, the advantage of such an approach is it allows analysing ecological incoherence. Pro-environmental behaviours are often not integrated, determining a trade-off effect which undermines the final result: for instance, solar parks produce renewable energy but entail sterilisation of farmland (Sacchelli et al. 2016).

Despite being useful, SPT seems less effective when we move from micro-situations to important choices or management of big organisations. It is the same difficulty that the nudge approach has to face vis-à-vis factories and managers. The practices one is helpful for understanding routines but less for accounting for crucial choices, like building a house or buying a car. In the last cases, we need a model of society able to formalise and abstract from thousand variants of action + situations. Thus, practices become an empty box in search of a framework. Traditionally, sociology adopted Weber's notion of rationality, with variable adjustments (types of rationality); subsequently, another representation of humankind has been the dramaturgy of Goffman, which has enjoyed a vast success. The great success of political ecology is a further sign of this search for filling the box of energy studies with a model (Cherp et al. 2018).

In order to reduce the instrumental attitude of above approaches such as political ecology, the game-playing metaphor has been recently introduced in environmental studies (Osti 2018, 2019). It should help to diversify the range of key factors able to assemble and give coherence to pro-environmental practices. Thus, the practices approach is completed with a general interpretation of social reality (model). It is intriguing that the

idea of energy transition can be used for representing the entire evolution of society (Carrosio 2014; Gabrys 2014).

The idea of social practices in search of a model is arguably a first result of our analysis. However, even social models may be blamed to be too abstract and rigid for energy studies. A way to keep both models and their concrete application to the variety of energy practices is to reduce the scale of abstraction and to focus on middle-range processes.

Relevant middle-range socio-technical processes for energy issues can be:

      i.   monitoring
     ii.   sharing
   iii.   playing

Monitoring. In the energy field, but common to all environmental issues, monitoring has a central role at the social level (Environment Management Group 2012). The success of or appeal to citizen science experiments (Wylie et al. 2014) reveals important things: there is great uncertainty on how complex systems work. Energy is one of these, even if more predictable and measurable than others. In fact, full automation of power plants or of home services does not solve the need for manual regulations. At the same time, diffuse generation and smart grids advance very slowly, because the interface with human agents is unpredictable and full of side effects. A way to circumvent this impasse, ostensibly, is monitoring. This should be done in terms of extensive and conscious participation, that is by establishing routines of self- or shared monitoring. On this point, there is major room for cooperation between social and techno-science practices.

Sharing. In the energy field, we noticed sharp differences in terms of the self-organisation of residential communities. In some European countries, energy communities have flourished; in Italy, they have flourished only in Alpine border areas. Evidently, cultural biases play a role since, for instance, other areas such as Central Europe generally have proven to be more innovative (Magnani and Osti 2016). Nevertheless, special and accidental combinations between social organisation and renewable energy packages have occurred. Both cultural determinism and technological determinism are to be abandoned. Case-by-case matching of community resources and energy packages has to be explored. Innovative models need to be identified, such as non-contiguous networks of citizens sharing green energy. For network configuration, different technological packages are necessary.

Playing. In the energy field, we have seen the desire for competition emerging as a leverage for inducing worthy behaviours. When experimental simulations are conducted, this emerges as a result, having thus an exemplary value. But we would be prone to believe that people participating in experiments contributing to calculate sets of statistics are not like Pavlov's dog, simply responding to a stimulus. *À la* Goffman (1961),

they can simulate, adapting to research expectations and playing the role of good test subjects. The role distance concept helps in this and in other cases to highlight the human capacity to play with others and with technological packages. We know role distance is relative and changing; sometimes the game itself takes the upper hand and everything becomes terribly confused for players themselves. Hence, a playing approach shows us the limited importance of experiments.

Conclusion

As a final remark, two further points can be highlighted: i) a plurality of positions and relationships among disciplines is beneficial to a better understanding of the energy issue; social sciences are not only ancillary to the 'hard' ones but can also tackle the root of the problems and help connecting complex systems. This has a symbolic and practical importance in projects concerning energy transition, which have often a multidisciplinary character. ii) There is a sort of circularity within social sciences: first, the relational perspective helps overcoming some limits of traditional holistic and atomistic approaches; then, practices theory adds to relations a spatial-temporal dimension; finally, and this closes the circle, practices need more general frames, an ideology or an anthropology, in order to cumulate knowledge, to compare different countries and to formulate previsions.

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Thinking about the Differing Contributions of (Social) Psychology and Sociology for Understanding Sociotechnical Transitions Perspectives on Energy Supply and Use

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Introduction: Socio-technical Transitions, Sociology and (Social) Psychology

Sociotechnical transitions thinking attributes our unsustainable development trajectories to complex and enduring interconnections between scientific and technological development, industry, markets, policy and culture. All are said to co-evolve in a complex system of mutual and usually self-reinforcing processes (Kemp et al. 1998; Geels and Schot 2007). There is some explicit discussion of ontology in (for brevity) the 'transitions' literature on this complex process of co-evolution, but it is arguably fair to say that this has rarely been a primary concern. Geels (2010) is a notable exception, as the author discusses how the transitions literature draws on social theory with a variety of ontologies, very often only in a tacit way; and how MLP fits into this variety, given its heuristic, integrative nature. More often than not, though, authors positioning themselves within sociotechnical transitions frames are more concerned with specific conceptual, theoretical and/or empirical aspects of their cases, than with discussing underpinning assumptions about the nature of the social world. Moreover, while the literature recognizes the importance and roles of individual actors, the agency of those actors - their capacities to act and the influences on those capacities - have been scarcely theorized (Bögel

and Upham 2018). It would seem that relatively little has changed in this regard since Genus and Coles (2008, p. 1442) observed that individual actors are often critical to changes in the 'rules' that are assumed in structuration accounts to pattern society. Geels et al. (2016) is one of the exceptions and we return to this in the last section; another recent contribution is Wittmayer et al. (2017), regarding actor roles; similarly, Fischer and Newig (2016); none, though, are concerned with the subjective experience of actors and the relationship of this to transitions processes.

In this context, the goal of this paper is to show lines for further development – of how theoretical accounts from transition studies, sociology and (social) psychology could be used, particularly in an interdisciplinary way, to improve our understanding of the subjective experience of individual actors and actor groups as an essential driver or barrier for sustainability transitions. For this purpose, we first outline the different assumptions characterizing the ontologies of sociology and (social) psychology via-à-vis transition studies; these assumptions will be the basis to continue with the question of how to bridge those different approaches. The focus for this purpose is on (social) psychological approaches and their potential crossovers with sociology, particularly social practice theory (SPT) and transition frameworks, as the role of psychology for understanding agency, and here particularly the role of subjective experience, in transitions is our main concern in this Crossing Boundaries.

Sociology in the Sociotechnical Transitions Literature

Sociotechnical transition researchers do acknowledge the role of subjective human experience, but mainly from sociological perspectives, which underlie the social foundations of transition frameworks (e.g. MLP, see Geels 2002; or the Triple Embeddedness Framework, see Geels 2014). For prominent sociological accounts in transition studies see studies on the roles of meanings, interpretation, discourses and symbols (Stedman, 2016) in transitions, understood from social perspectives, and in particular studies on the role of social practices for transitions (Köhler et al. 2019). In social practice theory, "routine human action is understood as a product of collective social practices influenced as much by the environment as it is by personal preferences or processes of deliberation (Köhler et al. 2019, p. 729)". Practices are thus a key unit of analysis. With roots typically in Bourdieu's (1977) theory of society as structured and stratified in part by repeated and routinized practice, this work has examined a range of practices with environmental and energy consumption implications (Hand et al. 2005; Shove 2010a).

While sociological or cultural accounts of subjectively-experienced phenomena place their focus external to the individual in terms of processes, psychology emphasises individual-level characteristics and processes. These processes may have a social dimension (e.g. the influence of social norms), but whereas: "sociologists generally devote their efforts to

identifying *which* social phenomena have effects on individuals" ... "psychologists generally specialize in *identifying the mechanisms or processes through which* social phenomena have their effect on individuals" (Thoits 1995, p. 1231).

Psychology in the Sociotechnical Transitions Literature

A recent literature review by Bögel and Upham (2018) shows the potential of (social) psychological approaches for improving our understanding of agency in transitions; but it also highlights the little use that sociotechnical transitions theory has made of psychology to date. The review shows that the primary use of psychology in this literature has been in relation to consumption and technology acceptance. Of the large variety of psychological perspectives and theories available, only six main theoretical perspectives have been deployed in the sociotechnical transitions literature, namely (i) rational and mindful decision making, with the Theory of Planned Behaviour (Ajzen 1991, 2011) being the most prominent approach and probably among the psychological theories most used in transition studies in general; (ii) habitualized behaviour, mainly studies from SPT perspectives and with new approaches emerging from identity theories; (iii) the role of norms, with e.g. norm-based approaches such as Stern's Value-Belief-Norm Theory (for an overview see Jackson 2005) being quite prominent in environmental psychology but rarely used in transition studies (with the Energy Cultures Framework by Stephenson et al. 2015 being an exception but quite differently premised); (iv) societal level theories, mainly represented by Social Representations Theory (SRT; Moscovici 2000); (v) place attachment, including place identity approaches; and (vi) information and persuasion approaches. Concerning social practice theory, it should be noted that while sociological in origin, as conceived by Bourdieu (1984) SPT has a social psychological component in terms of individuals' habitus and dispositions, offering cross-over potential between psychological and sociological perspectives.

Indeed, the meaning of the "social" in social psychology has developed over the years in two main directions, each producing a different view of what social psychology is and should be (Rijsman and Stroebe 1989; Rizzoli et al. 2018). In the first direction, the social is treated as an enveloping context and/or an applied topic, and the task of psycho-social research is to target universal individual-level processes: fundamental needs, core motivations, traits, and information processing capacities. These are seen as universal-individual-natural processes that often happen in social contexts and with social stimuli. An example of such a position is the suggestion that a "social" social psychology can be achieved by maintaining theorizations focused on the individual level, provided that group/societal processes are included in the research designs as pertaining to context (Taylor and Brown 1979). In other words, here the pro-

cesses to be studied are conceptualized at an individual level, whereas the topics analysed are social, and/or of social relevance (Rizzoli et al. 2018).

According to the second position, the social is neither an applied topic, nor an enveloping context (Batel et al. 2016; Batel and Castro 2018); the social is viewed as constitutive of the psychological, and the focus is on how meaning and action emerge from various (Subject-Other-Object) relations (Moscovici 1972). In this view, there is no stark distinction between the social and the individual (Greenwood 2014; Moscovici 1988; Reicher 2004): context and relations are not external/enveloping variables and for developing theories and research questions, social psychology needs to consider how social and historical facts constitute psychological subjects, relations and contexts (Gergen 1973). Many of the questions posed by this second direction are concerned with how psycho-social processes - such as social identification, communication, representation - are involved with how change and stability are both achieved and legitimated in societies (Castro and Mouro 2016). It is naturally the second line of research that lends itself more closely to integration with societal-level sociological and system-level transition studies frameworks.

Understandings of Agency and Action: Socio-Psychological Approaches and Their Implications for Energy Transitions

In this section, we consider two theoretical perspectives from the second line of social psychological research, namely SRT and identity approaches, for studying subjective aspects of agency in transitions. We do so on the premise that these perspectives: (i) offer particular insights into the behaviours and practices that structure societal relationships with technologies and systems of provision; and (ii) are amenable to a degree of integration or meaningful juxtaposition with the high-level process concepts of sociotechnical transitions thinking, to date focused more on collective than individual processes and experience. As empirical illustration of how the different perspectives complement each other (with connections to SPT), we take the case of energy supply and demand. While there are different policy implications deriving from the disciplinary ontologies (see e.g. Shove 2010b), analysts from different ontologies agree on the need for behaviour change as one characteristic of, or precondition for, a sustainable energy system. This agreement and the large variety of studies on this topic emerging from all these perspectives, including SPT, make energy supply and demand a suitable Boundary Object (Star and Griesemer 1989) to illustrate the theoretical perspectives, their differences but also possible points of connections.

Social representations theory (SRT)

SRT (Moscovici 1988) is a major social psychological theory about meaning-making and communication. It posits that social representations

have two functions. First, they conventionalise new concepts and give them a recognizable and common form, thus enhancing communication and coordination within a group: "These conventions enable us to know what stands for what" (Moscovici 2000, p. 22). Second, representations prescribe ways of thinking about topics: "they are forced upon us, transmitted, and are the product of a whole sequence of elaborations and of changes which occur in the course of time and are the achievement of successive generations" (Moscovici 2000, p. 24). Nevertheless, SRT also emphasizes how social representations change through interaction and communication, and as the social groups through which they travel change, also how new ideas, which in turn are anchored to older representations, constantly emerge from these processes and relations. In other words, SRT highlights how 'all encounters with the world are mediated through relationships' with other social beings (Castro and Batel 2008, p. 479) and hence how meanings are always relational and co-constructed (see Howarth 2006). This is often referred to as representations emerging from Ego-Alter relations, the site where meaning is not just constructed but also transformed. Moreover, SRT highlights also that these relations happen in a culture and are constrained by its institutions, and therefore that understanding meaning making requires taking into account the three dimensions of culture, context, and interaction, and acknowledging that these are not external variables (Batel et al. 2016; Castro 2015).

There is work drawing from SRT for examining energy representations and energy controversies. The approach has informed a theorization of local resistance to the construction of renewable energy infrastructures that views it as place-protective, arising from interpretations of the structures – through a community's shared representations and communications – as threats to place and to people-place relations (Devine-Wright 2009). Further, empirical analysis has shown how representations of the countryside or seaside are used by residents to make sense - and refuse – certain energy infrastructures (Devine-Wright and Howes 2010; Batel et al. 2015), or for demonstrating how the representations of energy in Italian political debates and newspaper articles bear witness to the prevalence of economic approaches and a view of citizens as needing to stay passive (Sarrica et al. 2014). Also, some work shows – through analyses of re-convened group sessions with citizens from two French communities where smart meters were first installed - how the shared elaboration in the groups led participants to consider more collectively-oriented approaches and goals to make sense of the meters (Bertoldo et al. 2015).

Identity theories

Two lines of identity-approaches will be considered here: (i) theoretical perspectives for the role of symbolic meaning for personal and social identity, offering crossovers to SRT and (ii) social identity theory. Regarding the first, namely meaning and identity, this perspective can be traced

at least to Mead (1956), who argued for a socially constructed nature of the self and the associated role of communication: "a self can arise only where there is a social process within which this self has its initiation. It [the sense of self] arises within this process" (Mead 1956, p. 42). This basic idea has continued through to contemporary accounts, in which material artefacts are assumed to have symbolic meaning derived through social negotiation and thence incorporated into a sense of self, with implications for behaviour, including consumptive behaviour (Jackson 2005) and energy demand. The meaning and the construction of meaning of these material goods is posited by Elliott and Wattanasuwan (1998) as shaped by three processes: lived experience, mediated experience and discursive elaboration. Lived experience relates to people's experience with artefacts, e.g. new energy technologies in their homes. Mediated experience relates to the presentation of symbolic resources in multiple forms of media, for example of different renewable energies. The process of discursive elaboration describes the negotiating of the symbolic meaning and the self with relevant others, e.g. friends, family and colleagues. Concerning the role of symbolic meaning and identity for energy demand and supply, Nye et al. (2010) suggest research focusing on social construction of identity and consumption may be a promising way to study habitualized behaviour; the basic assumption being that identity and lifestyle aspects are key drivers of energy behaviour. Nye et al. (2010) mention the example of air conditioning as a symbol of modern life. Likewise, lighting can be interpreted as a symbol for prosperity. While the authors focus in their suggestions on everyday energy demand, the role of symbolic meaning and identity might also be extended to acceptance studies, offering also potentials of crossovers between SRT and symbolic meaning and identity-approaches, discussed in more detail in the following section.

The second theoretical perspective, namely Social identity theories view identity as an interplay of societal and individual processes, despite being primarily social psychological in nature. An example is the approach of Schmid et al. (2011), which encompasses Social Identity Theory and Self-Categorization Theory, and assumes that individuals apply distinct social categories to understand their social world, such as gender or professional categories. These categorizations create in-groups and out-groups, which in turn influence individual (and group) attitudes and behaviours. In this respect, social identity theory has been described as being "at the heart of social psychological theories" (Schmid et al. 2011, p. 211) and is applicable to a wide range of social contexts and processes. Such contexts include institutions, organisations, firms, governments and consumers in aggregate or as sub-groups. With regard to energy demand and supply, individualistic psychological approaches have been in the focus of research but recently authors have started to study the role of social identity for both (i) household energy and (ii) the growth of community energy (or other social movements), addressing the changing role of

consumers (towards prosumers) in energy systems. Concerning (i), Mäkivierikko et al. (2019) build on both the Theory of Planned Behaviour and Social Identity (see also Fielding et al. 2008) and examine the influence of social identity among neighbours on energy demand reduction. Concerning (ii), previous studies have recently started to discuss the role of identity for the development of social movements in general – either as a driver or barrier for social diffusion – (Seyfang and Haxeltine 2012) - and community energy in particular (e.g. Pohlmann and Colell 2017).

Theoretical Crossovers between SRT, Identity Approaches and SPT

In the following, we discuss possibilities for theoretical crossovers between SRT and identity theories as well as their potential cross-overs with SPT, with a separate discourse on the social psychological elements of SPT *per se*; the overall purpose is a richer understanding and theorisation of actor-level experience in sociotechnical transitions processes. We start with discussing potential crossovers between the social psychological accounts presented here, namely SRT and identity-approaches. There are clearly many points of connection between the psychosocial approaches considered here. At the core of these connections is the construction of meaning, or sense-making, which has implications for identity and action, practice or behaviour. In the previous section, we already mentioned the possible extension of approaches on the symbolic meaning and identity to acceptance studies and the potential that this offers for crossovers with SRT. In fact, Elliott and Wattanasuwan (1998) some 20 years ago suggested to study the connections between the concept of social representations and their theoretical model on the construction of meaning and identity with regard to social-symbolism: "The concept of Social Representations could also be adopted to explore the socially shared meanings of consumption." Likewise, Castro (2003), citing Parker (1998) identifies points of connection between the two approaches: "the social psychological theory of social representations was part of a sustained attempt by the discipline to develop fully social explanations of identity and shared knowledge." This line of research could examine the role of social representation in relation to identity-processes, in turn with implications for further development of social representations, e.g. taking into account the findings on the role of social identities for joining community energy initiatives, or for the study of groups with contrasting social representations as often found in energy controversies. Such a line of research would take into account the ways in which action is shaped by in-group and out-group formation, in which social representations of all types of phenomena play a role. Vis-à-vis SPT, this would offer the possibility of studying individuals as agents of transitions rather than as passive objects; which

would be a key step forward given that a key critique to SPT approaches is the rather passive role that SPT ascribes to individuals in transitions. Further cross-overs between SRT and SPT in particular (see also Batel and Castro 2016) could start at the obvious insight that we inhabit a material world as well as an ideational one. Materiality and embodiment are where SPT can complement SRT, to more fully conceptualise and examine the roles of technologies, infrastructures and also biophysical systems involving non-human actors (Batel et al. 2016). In turn, SRT can add to SPT in at least two ways. First, by conceptualizing people as agentive in bringing about social change, and second by offering an account of the role of Self-Other and power relations in allowing, constraining, and/or enabling (Batel et al. 2016). In addition, SRT helps to understand specifically how new scientific knowledge is appropriated and becomes used as common sense in everyday lives. As such, it helps examine cultural and techno-scientific change and how this is appropriated in contemporary heterogeneous public spheres (Batel et al. 2016). Overall, SRT and identity-approaches may complement SPT by adding psychological dimensions without being overly-individualistic in the resulting account.

Conclusions and Further Research

Going forward, the previous section has set out general and specific options for further research on subjective experience in relation to sociotechnical transitions processes. A more extended range of suggestions as regards social psychological perspectives and also research design for multi-level work is given in Upham et al. (2019). We are only just at the beginning of the process of making further, close connections, arguably in part because disciplinary affiliations have hindered interest in making such connections (Bögel and Upham 2018). Cases of sociotechnical change are so complex and multi-layered that it is unlikely that we can neatly map a differentiated correspondence or suitability of different social psychological (or more broadly, psychosocial) theories, perspectives and empiric research for connection to core sociotechnical concepts and processes features - as, for example, represented in the MLP framework (Geels 2002), or in idealised typologies of sociotechnical change (Geels and Schot 2007; Geels et al. 2016). Rather, it is more plausible that psychosocial perspectives can be applied on a case by case basis, while considering the possibilities for generalisation, to help give a fuller account of the processes involved.

This will be facilitated where agents are not only acknowledged as important but are given a more central role. The local enactment approach of Geels et al. (2016) is one such starting point, as is earlier work to which the authors refer (Geels 2004; Geels and Schot 2010). All of the latter emphasise the roles of individual actors and social groups in competing and collaborating to shape relevant social rules and institutions. While

Geels and Schot (2010) refer to the option of analysing at different levels of 'granularity' (resolution or scale), they take the view that case-specific scale analysis may be less useful for the conceptualisation of transition pathways, which aggregate over time. We acknowledge that theoretical or conceptual connections between processes at very different scales are inevitably indirect, highly mediated and moderated as well as probably difficult to be definitive about tracing causal processes. Adding a psychosocial layer of analysis adds to the challenge. Yet these issues are inherent to multi-level analysis. Moreover, psychosocial processes are generally not stochastic: people are for the most part consistent and rule-following, seeking stability. These processes should be amenable to conceptual and theoretical connection to other conceptions and theories of sociotechnical change at different scales. What is at issue is the degree of conceptual or theoretical integration that is possible, and this is largely a function of the ontologies underlying particular concepts - hence our starting point. We hope that this short paper encourages further work along these lines.

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[1] For a review of the different approaches to SPT and its theoretical development, see Postill (2010). There is a very active community of scholars dealing with the study of practices through a wide array of methodological approaches. As Hui and Schäfer declare in the blog PracticeTheoryMethodologies, there is no unique perspective on the study of social practices, but rather "diverse approaches and conceptual vocabularies within the broad 'family' of theories, in contrast to individualist or normativist positions" (https://practicetheorymethodologies.word press.com/about/ retrieved on October 17, 2019). For this reason, it may be more appropriate to talk of "theories", rather than "theory".

[2] I am grateful to Paolo Volontè for discussion at the seminar 'META', Politecnico di Milano (5 June 2018), from which this paper is drawn.

Learning as a Matter of Concern
Reviewing Conventional, Sociocultural and Socio-material Perspectives

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Abstract: Early progressive and sociocultural theories in education share unexpected similarities with recent research concerned with the socio-materiality of learning settings. Therefore, this scenario retraces the shift from learning as transmission and guided rediscovery towards a performative account of learning as translation. In particular, this paper elaborates the differences between conventional, sociocultural and sociomaterial approaches regarding the unit of analysis, the mediation done by nonhumans and the contemplation of more fluid forms of knowledge. While retracing conceptual links and developing a sociomaterial conception of teaching(-)learning, I argue that the recent line of sociomaterial research carries on what early authors have been aiming at with the idea of practice-based, non-reductive educational science. But, due to its alternative stance on common onto-epistemological assumptions, it opens up new possibilities of collaboration between Science and Technology Studies and educational sciences where the agency of things and the mediation of knowledge emerge as matters of concern.

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1. Introduction

Over recent years, a growing variety of research has been concerned with learning and teaching while following a "post-humanist socio-material tradition of ANT" (actor-network theory) (Sørensen 2007, 16). Among these, we can count studies about the role of objects in classroom interactions (Verran 1999; Sørensen 2009; Röhl 2012; Mulcahy 2012;

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Landri and Viteritti 2016), computer assisted instruction and e-learning (Nespor 2011; Thompson 2012), workplace practice in organizations (Orlikowski 2007; Mathisen and Nerland 2012), informal "everyday" learning (Aberton 2012) as well as detailed descriptions about the enactment of prescribed curricula and teacher standards (Edwards 2011; Ceulemans et al. 2012), educational reform (Hamilton 2011) as well as educational assessment procedures (Gorur 2011). All these authors study a world made of "concatenations of mediators" (Latour 2005, 59). Yet, the relatively recent concepts of "relational materiality" and "performativity" (Law 1999) in Science and Technology Studies (STS) also bear some resemblance to the following citations published many years ahead (emphasis added):

> As a result, the immediacy of 'natural' perception is supplanted by a complex *mediated* process; as such, speech becomes an essential part of the child's cognitive development. (Vygotsky 1978, 32)

> [...] we introduce no *knower* to confront what is *known* as if in a different, or superior, realm of being or action; nor any known or knowable as of a different realm to stand over against the knower (Dewey and Bentley 1949, 136)

> Educational influence is *diffused* through *all the surroundings*, and persons, children and teacher, come to take their share, in it. (Montessori 1948, 95)

Although these authors worked separately from each other and in different parts of the world, they all made early contributions for the reconfiguration of learning environments. Their theories reshaped material-discursive practices concerning learning. This is why nowadays there is a recurring interest in progressive education practice and sociocultural perspectives of learning. Looking back at past work, some of their descriptions may sound strangely familiar today. More specifically, considering the importance of "prepared environments" (see Brehony 2000) and the active role of materials in Montessori's pedagogy, it was not necessary for her to read about the "distribution of competences between humans and nonhumans" (Latour 1992, 158) in order to state that the "work of education is divided between the teacher and the environment" (Montessori 1948, 196).

Dewey, Montessori and Vygotsky offer different, but overlapping perspectives on education that explore a non-dualistic alternative to widespread mechanistic views on education at that time (Tolman and Piekkola 1989; Prawat 2000; Bodrova 2003). Indeed, progressive education, sociocultural psychology and recent sociomaterial studies in STS share an interest in the material circumstances and treat learning and teaching as *matters of concern* (Latour 2005) rather than matters of fact. While "starting from observations of real life situations" (see Lee 1984, 107), the intent of most progressive education advocates was to offer a modern,

scientific method of designing education practice. Instead of being a complete solution, Montessori (1948, 388) saw her schools as empirical laboratories for 'experimental pedagogy'. Or, for instance, Freinet searched for a "pedagogical style based on intuition and observations of young children" (Nowak-Fabrykowski 1992, 64). In a similar vein, Vygotsky has based his "experimental-developmental" method in psychology on "experimental interventions and observation" (Vygotsky 1978, 14, 61).

Similarly, today, many authors follow Law (2009a, 141) in treating ANT as a "disparate family of material-semiotic tools, sensibilities, methods of analysis" (see also Nespor 2011; Gorur 2011) instead of suggesting it to be a theory whose "centre has been fixed, pinned down, rendered definite" (Law 1999, 2).

From there, this article fits in with an effort to review how a similar mindset in approaching teaching and learning has produced a variety of influential concepts over many decades, in concordance with larger changes in social sciences, such as the "practice-turn" (Hager 2012; Grasseni and Ronzon 2004) and efforts "to develop non-foundationalist and non-representational ways of researching the social" (Fenwick and Edwards 2013).

Sociomateriality, in this regard, is one of the latest developments concerning practice. As Gherardi (2017) points out, 'sociomateriality' emphasizes the entanglement rather than the separation of the material and the social and is linked to practice-based studies of organization. In its current usage without hyphen, Orlikowski (2007, 1446) established it as a way to "investigate the multiple, emergent, and shifting sociomaterial assemblages that constitute organizations". In short, it underscores the *constitutive entanglement* of the material and the social (Orlikowski 2007). According to Fenwick and Edwards (2013), recent developments in ANT as well as in cultural-historical activity theory (CHAT), which builds on Vygotsky's work, qualify as sociomaterial approaches. The latter are characterized by materiality, inseparability, relationality, performativity and a focus on practices (Gherardi 2017).

But, why should educational researchers adopt such a sociomaterial perspective, and how can STS make use of existing links to educational approaches? Hereafter, in an attempt to bridge the gap between existing pieces of theory about learning, I outline a set of key concepts and conceptual problems and how these can be dealt with from a sociomaterial perspective. In Table 1, we see how key concepts about learning differ with the change of perspective, which I will elaborate in more detail below.

	Conventional paradigm	Sociocultural approach	Sociomaterial approach
Unit of analysis	the mind of the learner	the learner's community of practice and zones (ZPDs) of joint construction	sociomaterial assemblage, actor-network
Participation of objects	object viewed either as tool (intermediary) that extends human decisions, or as a cause that determines human performance	acknowledged mediation of objects in learning, interaction with objects in scaffolds and didactic material	no formal distinction between human and non-human actors, every object (including mundane objects) is allowed to make a difference
Spatial configurations	classroom conception, learning spaces seen as confined regions	learning in prepared environments, can extend beyond classrooms	relations unfold in multiple spatial topologies (*e.g.* regions, network, fluids)
Relation knower-known	knower disconnected from disembodied knowledge	knowledge related to skill, situated in practice	embodied knowledge inseparate from knower
Learning 'transfer'	transmission and abstraction	learning as guided rediscovery in a similar practice	through materiality of learning, teaching(-)learning as translation/propagation
Agency and actors	pre-existing roles and entities, teacher centrality	roles can be reconfigured, teachers as facilitators of the student's own learning	teacher/learner as effect, actors are performed through entangled teaching(-)learning

Table 1 - Theoretical perspectives on aspects of teaching(-)learning (own elaboration).

2. Learning as Transmission, Construction and Participation

According to Rogoff and Toma (1997, 474), most public schools follow a *'transmission model of instruction'* with "basically dyadic" interactions. They are most commonly structured through teacher-centered whole-class teaching. From this perspective, the teacher is the one who applies and displays knowledge, whereas the pupil passively picks up the knowledge. Authors pertaining to classic progressive education, practice-based research as well as sociomaterial studies oppose the reduction of teaching "to narrowly specific prescriptions for what should be transplanted into the heads of kids" (Lave 1996) or where "the dignity of man

is reduced to the level of the dignity of a machine" (Montessori 1948, 17).

Alternative teaching methods in education have been called "constructivist" as they emphasize the child's own construction of knowledge (see also Kamii and Ewing 1996). But, as Rogoff (1994, 212) points out, original authors also distanced themselves from schools that reduced the ideas of progressive education to be a simple reversal of control in the classroom (see also Dewey 1938). Therefore, one must not understand these approaches to be about leaving children to their own devices. One tends to divide education into two extremes that either neglect the input from the learners or from the teachers in a "pendulum swing between control and freedom" (Rogoff 1994, 210).

According to Montessori (1948, 197), the teacher "does nothing more than facilitate and make clear to the child the very active and prolonged work which is reserved for him" or her. This, however, is a constant, continuous effort comparable to that of a "guardian angel of minds concentrated in efforts which are to elevate them" (ibid.). In Dewey (1916/2001, ch. 22) we see that authority does not disappear, but it is distributed as 'social guidance' instead of authoritative dictation.

Thus, focusing on the theory of learning as a whole, constructivist methods imply that new classroom configurations afford not yet another form (or reversal) of transmission. Rather than isolated knowledge construction, we have to picture learners as "active agents in the material world" (Fenwick and Edwards 2013, 50) and focus on their interactions and activities. To illustrate this point, a key concept is Vygotsky's "zone of proximal development" (ZPD) which he defines as follows:

> It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (Vygotsky 1978, 86)

Thus, Vygotsky (1978) questions the notion of imitation and learning as being "purely mechanical". Rather, the ZPD signifies the child's potential of development as the result of social interaction. Interestingly, we can encounter the ZPD also beyond intentional instruction. We are able to look at certain kinds of play that are "responsible for creating young children's 'zone of proximal development' " (Bodrova 2008, 360). Vygotsky (1978, 102), for example, describes, how, in make-believe play, it is as though the child was "a head taller than himself" and behaves beyond his or her age. To underline the importance of the social and material context of activity, Newman and colleagues (1989) identify the ZPD as a joint "construction zone". In fact, scholars of cultural-historical activity theory have gradually widened their focus from *cultural mediation* (Vygotsky 1978) to *collective activity* (Leontiev 1981/2009) and to *interconnected activity systems* (Engeström 2001).

In a more anthropological account, Tim Ingold (2001) promotes an

understanding of *guided rediscovery* in *taskscapes* where "knowledge consists, in the first place, of skill" and "where every human being is a centre of awareness and agency in a field of practice". Thus, either by learning in the ZPD, or through rediscovery in a "taskscape", the environment "is not merely a source of problems, of adaptive challenges to be resolved; it becomes part of the means for dealing with them." (Ingold 2001, para. 25).

Regarding the social environment, another relevant sociocultural concept is learning as "an aspect of changing participation in changing communities of practice" (Lave 1996, 151). In this approach, the *community of practice* provides information, resources and opportunities for participation that enable learners to access membership in the community, i.e. to change identity and to learn (Lave and Wenger 1991).

Despite the different origins, Star (1995) shows that the "community of practice" and the ZPD are linked to important concepts related to symbolic interactionism. According to her, both the ZPD and the "matrix" in grounded theory (Strauss 1993) "are created through shared practice and co-constructed material conditions, both very local and highly extensive" (Star 1995, 14). In addition, we can define the "social world" as well as the "community of practice" as the main *unit of analysis* for the organization of people's collective learning (ibid.).

Hence, without adopting a strict sociomaterial perspective, we have already reached an understanding of learning with a broader unit of analysis, which allows us to look at the distribution of cognition (Cole and Engeström 1993). In the account of *distributed cognition* by Hutchins (1995), for instance, cognitive processes *emerge* from interactions within *cultural cognitive ecosystems.* Such a cultural cognitive ecosystem "includes a shared world of objects and events as well as adaptive resources internal to each member of the community" (Hutchins 2013, 4).

In sum, we reached a common departure point for a sociomaterial analysis that emerged from different directions. Concerning our widened scope, according to Fenwick (2010, 111), sociomaterial approaches commonly "take the whole system as the unit of analysis, appreciating human/nonhuman action and knowledge as entangled in systemic webs". Another step would be not to "privilege human consciousness or intention, but trace how knowledge, knowers and known (representations, subjects and objects) emerge together with/in activity" (Fenwick 2010, 112). To continue on this path, I next clarify the role of objects, or "nonhumans", in relation to learning.

3. From Tools over Scaffolds to the Participation of Objects

Considering the importance of things and objects in education, con-

ventional research has been rather human-centered or (techno-)deterministic. According to Waltz (2006, 52), over the years serious work "has gone into the development and use of things as educational tools". Less attention, however, has gone into the theory regarding things. They are either framed as "subordinate tools serving human aims or, by contrast, primary movers and therefore overdetermined agents of change" (Waltz 2006, 54). Thus, drawing from ANT, a reconsideration of nonhuman actors can enrich educational research. Namely, it helps discern the contribution of objects in shaping classroom interactions without falling back to binary thinking.

For this reason, I now explore notions of objects beyond the image of mere tools of instruction. For example, in sociocultural learning theory, another widely used metaphor for work with artifacts is "scaffolding" (Wood et al. 1976). With regard to the ZPD, the notion of 'scaffolding' has been introduced to describe the process where a tutor helps somebody who is less expert in the achievement of a problem solving task. In this case, rather than direct usage, the teacher prepares materials for the interaction with the learner in order to make the task more manageable. According to Pea (2004), the employment of *fading* is an essential aspect during work with materials and artifacts crafted specifically for scaffolding. Similar to the dismantling of building scaffolds, the support of the scaffolding or the participation of the tutor gradually fades away as the child achieves autonomy (see also Newman et al. 1989). The term "scaffolding", however, should not be understood as a "one-way" process where the "scaffolder" constructs the scaffold alone and presents it (Daniels 2007, 318). According to the critique of Newman and colleagues (1989), the ZPD is rather created through negotiation between participants.

Therefore, the discussion of "scaffolding" takes us one step nearer to the consideration of the agency of things. In sum, we can understand the construction of the ZPD in relation to a system of multiple contributing human and nonhuman actors where the child moves actively using her own creativity. To illustrate that point, we can rely once more on Montessori, who explains the difference of her *materials of development* and normal tools or "means of teaching" as follows:

> The profound difference [...] is that the objects are not an aid for the mistress who has to explain, that is they do not constitute means of teaching. But they are an aid for the child who chooses them himself, takes possession of them, uses them and employs himself with them according to his own tendencies and needs and just as long as he is interested in them. In this way the objects become means of development." (Montessori 1948, 197)

The teacher takes part in the performance of means of development. She arranges and introduces objects according to the needs and 'initiates' the child "into the ordered and active life of the environment" (Montes-

sori 1948, 95). There is, however, an important difference to conventional scaffolding. "Fading" is not employed by the tutor, but performed by the child who looses interest. We can even go further and imagine scaffolding in the absence of a "scaffolder". One may consider, for example, "forest schools" where natural (non-prepared) environments are known to stimulate the child's creativity (OBrien 2009).

In consequence, often the question of "who teaches" and of "who" provides scaffolding cannot be answered clearly. In other words, looking at human intentionality alone brings us to what Latour (2005, 45) calls the 'under-determination of action'. This is why our focus has to shift from the relations between performances of people towards the inclusion of nonhumans actants as well.

On that premise, it is necessary to highlight the meaning of objects as *mediators*. For instance, while sociocultural accounts stress that human action and learning is shaped by *mediational means*, these are often used as synonym for "cultural tools" (Wertsch and Rupert 1993). But, the image of *cultural tools* that mediate leaves a perplexity to resolve. Namely, how can a tool, which usually is used *by* another acting person or group (thus, passing their action along as an intermediary), simultaneously be a *mediator* that shapes action?

To shed light on this question, a crucial key to avoid confusion is to distinguish between *mediators* and *intermediaries*. According to Latour (2005, 39), an *intermediary* is "what transports meaning or force without transformation: defining its inputs is enough to define its outputs." *Mediators*, on the other hand, "transform, translate, distort, and modify the meaning or the elements they are supposed to carry" (ibid.). Therefore, all mediators perform relations and thus contribute to the outcome of situations, As a result, the question that underpins any analysis is whether we are "talking about causes and their intermediaries or about a concatenation of mediators" (Latour 2005, 62). Hence, when talking about objects as mediators, this is done without reducing the rest to mere intermediaries. As could easily be misunderstood, objects neither replace humans as causes of actions nor they acquire human intentionality. Rather, in a sociomaterial conception, causes and effects are distributed among heterogeneous actors. In short, "agency is not aligned with human intentionality or subjectivity" (Barad 2003, 826). According to the concept of *relational materiality*, the latter, along with divisons and distinctions such as human/non-human are now understood as effects or outcomes (Law 1999). This can be applied to the agency of scaffolds and cultural tools, too.

Looking again at Montessori (1948, 95), she talks about the educational environment as the "whole assemblage[1] of things from which the child is free to choose for using just as he pleases". But, she gives also a vivid description of what now can be interpreted as the agency of educational objects and their "voices":

> The teacher superintends, it is true; but it is the things of various kinds which call to children of various ages. Truly the brilliancy, the colours, the beauty of gaily decorated objects are no other than voices which call the attention of the child to themselves and urge him to do something. Those objects possess an eloquence which no mistress can ever attain to: 'Take me,' they say, 'see that I am not damaged, put me in my place.' And the action carried out at the instigation of the things gives the child that lively satisfaction, that access of energy which prepares him for the more difficult work of intellectual development. (Montessori 1948, 119)

At the same time, however, the teacher has a central role in this assemblage, she "is, in the main, a connecting link between the material (the objects) and the child" (Montessori 1948, 197). To some, this formulation comes as a surprise, as, in common language, we tend to treat objects contrariwise. They are, generally, the connecting link (intermediary) between human actors. Yet, neither the teacher nor the environment transport meanings without transformation, but are participants. Accordingly, given these points, we are now able to conceptualize the agency of humans and nonhumans alike, without neglecting a substantial part of relations that are performed during teaching and learning.

4. Spatial Configurations and Forms of Knowledge

Depending on the type of relations performed through teaching and learning, we can imagine different forms of knowledge. In education, the most common opposition between imaginaries[2] of knowledge is constituted by *representational* knowledge versus *situated*[3] knowledge. These are linked either with a transmission conception of learning or a constructive/discovery model.

As Wineburg (1989) highlights, progressive education authors like Dewey anticipate modern instructional approaches that account for situated cognition in communities of practice. Among the latter I count teaching strategies such as "cognitive apprenticeship" based on "enculturation" (Brown et al. 1989), "reciprocal teaching" (Palinscar and Brown 1984), "knowledge building communities" (Scardamalia and Bereiter 2014), "anchored instruction" (Vanderbilt 1990) as well as other kinds of situated, cooperative learning through teacher-guided discovery. While the two opposite learning paradigms appear to be incompatible to each other, it is possible to either claim all knowledge to be cognitive representations, or, as Lave (1996) sustains, view learning in general as "socially situated", which would then also include all abstract knowledge produced by "decontextualization practices". Nevertheless, classroom teaching, can benefit from a perspective on situated learning that also values mental work on symbolic objects, which is why Bereiter (1997) argues for "the value of thinking of situatedness as varying along a continu-

um".

In other words, how we think about knowledge depends on the configuration of knowledge-making practices we are trying to observe. Verran (1999) provides a telling example of this by confronting the teaching of metric units in the western tradition and in Nigerian (Yoruba) classroom practice. She concludes in highlighting the process of embodiment of knowledge, seen "as a co-constituted embodied participation in collective acting" (Verran 1999, 149). Therefore, we are able to retrace how children pick up public knowledge about quantification through embodied processes in classroom practice.

Given the importance of shared practice and embodied participation, it is useful to look in more detail at the concept of practice from a sociomaterial perspective. In ANT, Law (2009b) defines practices as "assemblages of relations". According to Orlikowski (2007, 1445), practices perform sociomaterial assemblages that bind together a "heterogeneous assembly of distributed agencies". Similarly, Gherardi (2017) shifts from a conventional understanding of practices as "arrays of activities" towards practice "as a mode, relatively stable in time and socially recognized, of ordering heterogeneous items into a coherent set" (Gherardi 2006, 36).

Thus, if we analyze teaching and learning as parts of one sociomaterial teaching(-)learning practice, we need to dis- and reassemble teaching and learning, recognizing the patterns and "forms of presence" (Sørensen 2007) of its heterogeneous, sociomaterial assemblage. In the light of this task, Mol and Law (1994) have established the possibility of multiple spatial topologies to characterize the social world. Namely, they distinguish between *regions*, *networks* and *fluids*[4].

The first spatial configuration "is regional and homogeneous, which distinguishes its objects by talking of territories and setting boundaries between areas" (Mol and Law 1994, 659). According to Sørensen (2009), the classical whole-class teaching set-up produces "regions" that separate children from the knowledge represented by the teacher and the blackboard. On a closer look, materials of instruction such as the blackboard "direct the gazes of the students" and configure students as "recorders of a relatively stable and public knowledge that can be reproduced" (Röhl 2012, 64). Thus, regional spaces perform boundaries and *representational knowledge* (Sørensen 2009, 102).

With the *network* spatiality, on the other hand, one describes relations "as composed of immutable mobiles" that have "invariable links between them" (Mol and Law 1994, 663). These *immutable mobiles* (Latour 2005) are actants that cross boundaries in time and space while being drawn together. As such, networks can produce resonance spaces where elements acting as an "obligatory passage point" draw together material and human participants and form "communal knowledge" (Sørensen 2009, 109). To illustrate this, a fitting example in teaching practice is "collaborative knowledge building" in "knowledge building communities" (Scardamalia and Bereiter 2014) that are focused on producing and improving

knowledge objects that can be seen as such passage points for communal knowledge, without the prior provision of external "facts" or "truth".

Concerning the third spatial topology, i.e. *fluids*, social objects "draw upon and recursively form fluid spaces that are defined by liquid continuity" (Mol and Law 1994, 659). Here, objects aren't well defined and do not always have clear boundaries. Also, "there are mixtures and gradients" and "the world doesn't collapse if some things suddenly fail to appear" (ibid.). Interestingly, stability is achieved by fluid continuity. While networks risk to fall apart because "things that go together depend on one another", in fluid spaces "there is no 'obligatory point of passage' " (Mol and Law 1994, 661). According to Sørensen (2009), "liquid knowledge" is formed through such fluid patterns of relations. The idea of fluidity is recurrent in sociomaterial accounts of informal learning. Aberton (2012) describes the material dimension of everyday learning and its liquid form of local, uncodified and often invisible knowledge that is not controlled, or "colonized" by a pedagogic authority. Similarly, Postma (2012, 152) associates learning in fluid spaces with "invisible pedagogy" (see also Bernstein 1975). Arguably, the latter kind of pedagogy fits in with aspects of alternative, progressive education efforts. There, the teacher also takes the form of an "arrangeur" and the "control of the teacher over the child is implicit rather than explicit" (Postma 2012, 152). For instance, make-believe play among children performs learning in fluid patterns of relations, but can also be facilitated, or "scaffolded" (Bodrova 2008, 366) and subsequently embedded in other learning activities.

5. From Learning Transfer to Translation

How do multiple forms of knowledge relate to each other? In this regard, a socomaterial approach can help us to clarify another conceptual problem about learning, i.e. *learning transfer*. Sørensen (2009, 177) identifies learning transfer as "a crucial problem in theories of learning". From a cognitivist viewpoint, it is not clear how knowledge is transferred into the heads of the students and then decontextualized so that it can be applied at any time and any place. Regarding situated knowledge, too, transfer may occur only when "constrains and affordances" are "invariant over transformations of context" in different situations, as has been sustained by Greeno et al. (1993) (cited in Allal 2001, 412).

But, actor-networks that situate practices are not bound to single contexts. In a sociomaterial conception, Fenwick and Edwards (2011) stress the importance of "observing the proliferation of practices and meanings as different worlds", where *multiplicity*[5] signifies the "enactment of distinct and different, often overlapping, ontologies". Thus, to explain situative/situated learning transfer we may also look at how different social worlds overlap and are connected by "fluid objects" (Law and Single-

ton 2005) or by what we can qualify as *boundary objects*. The latter have "different meanings in different social worlds, but their structure is common enough" to make them recognizable and inhabit more than one world (Star and Griesemer 1989, 393).

As Sørensen points out, the original conception of situated learning takes a regional imaginary for granted. In situated/situative accounts of learning, however, knowledge is not situated in the mind but in a multiplicity of practice (Sørensen 2009). In a similar vein, Mulcahy (2013) argues for a conception of transfer that "far from being transcendent" is seen as performed "differently in different sociomaterial practices and arrangements". Thus, how learning connects to other entities is concerned by what Sørensen (2009, 177) calls 'the materiality of learning':

> The materiality of learning must thus be understood as the achieved ability of a growth in knowledge to connect to other particular entities.

By viewing material relations, however, we see that transfer entails transformation, which is why authors use the concept of *translation* (Callon 1984) as an alternative metaphor for transfer (Mulcahy 2013, 1278). According to Sørensen (2009, 181), for instance, we deal with a multiplicity of overlapping spatial configurations, where sociomaterial processes such as bracketing, recording, or memorizing, don't transfer, but translate and thus change "knowledge from liquid to representational". By the same token, Latour (1995, 56) argues that cognition is studied best by following the "trajectories of modified representations", as he describes cognition as "propagation of representations through various media". Yet, the propagation described by Hutchins (1995) "does not mean transportation without deformation, but a modification, a translation, a shift" (Latour 1995, 57). Therefore, researching teaching and learning with a sociomaterial perspective allows us to trace associations and relations among "the social, textual and material elements of multiply interrelated settings" Mulcahy (2013, 1287).

6. The Performance of Teaching(-)learning

Having discussed the question of "who teaches" from the perspective of transfer and knowledge representation, ANT rather asks the question of "how it is that things get performed (and perform themselves) into relations that are relatively stable and stay in place" (Law 1999, 4). Therefore, we now shift from a representationalist to a performative account of learning.

As we have seen, the above mentioned problem of learning transfer is linked to the imagination of a separate known and knower that have nothing in between them apart from an "abyss between words and world" (Latour 1999, 121). Notably, this has already been criticized by authors like Dewey who rejects "the 'no man's land' of words imagined to

lie between the organism and its environmental objects" (Dewey and Bentley 1949, 136). In fact, Fenwick and Edwards (2013, 50) see Dewey's conception of learning emerging through transactions as the inauguration of "a sociomaterial view of education". Actually, both older (Dewey and Bentley 1949) and newer criticism builds on the discussion of onto-epistemological assumptions in quantum physics and its conflict with traditional representationalism. Introducing a more recent line of thought, Barad (2003) offers a posthumanist performative account that she coins 'agential realism', in which boundaries between matter and meaning, human and non-human, subject and object are performed through *intra-actions*. If we look at the moment of observation as an intra-action, for instance, it is the observation that performs an 'agential cut' that produces causes and effects. As Gherardi (2017, 41) acknowledges, Barad's posthumanist conception allows us to think differently about knowing:

> [...] the knower is not external to or pre-existing the world. Rather, the knower and the 'things' do not pre-exist their interactions but emerge through and as part of their entangled intra-relating.

Thus, we may think of the learner, the teacher as well as of the participating environment as entities that don't pre-exist. Rather, they emerge through their entangled intra-relating in practice. At the same time, teaching and learning can be seen not as two separate processes, but as parts of a "unified teaching-learning continuum" (see also Zürcher 2015, 79). Questions concerning agency, subjectivity and intentionality are thus disconnected from individual bodies. In consequence, one can retrace how "the teacher" emerges out of a sociomaterial assemblage, how the teachers' profile, for instance, is stabilized and "black boxed" as a profession (Ceulemans et al. 2012). On the other hand, however, we are also able to provide a sociomaterial interpretation of Montessori's "educational influence" that is "diffused through all the surroundings" (Montessori 1948, 95). In this light, I argue that teaching(-)learning (or *teachinglearning*[6]) as one sociomaterial practice continuously translates, assembles and guides the making of relations in a changing sociomaterial assemblage. This, in order to qualify as learning, must enhance the learner's ability to either represent these relations as acquired knowledge (in a cognitivist perspective), or to participate in communities of practice (in a situated-knowledge perspective).

At the same time, depending on the type of spatial imaginary one uses, different forms of knowledge, actors and roles result either as more evident or less visible. Consequently, in teaching(-)learning, we understand teaching and learning not as actions of pre-determined human subjects, but rather as the two ends of the same translation/propagation process. Rather than two separate activities, teaching and learning are two perspectives towards one practice. From the viewpoint of teaching, teachinglearning appears as continuous assembling effort. From the viewpoint of learning, teachinglearning results in (partial) internalization

(Latour 1995) as well as in participation, which results as the increased ability to "connect to other entities" (Sørensen 2009, 193).

All things considered, we have now moved across different interpretations of teachinglearning. To summarize the main characteristics of sociomaterial teachinglearning, we shall briefly reconsider Table 1. Departing from a conventional or 'standard paradigm of learning' (Zürcher 2015), I gradually passed to important sociocultural notions that prepare for a full appreciation of sociomateriality. In the first row, we see how the unit of analysis shifted gradually from the individual mind to the joint construction of the ZPD in a community of practice and eventually to the sociomaterial assemblage that accounts for both human and nonhuman actors. Accordingly, objects now participate as mediators, rather than being a mere intermediary or tool of a teacher. As we see in the second column in Table 1, this has already partially been the case with regard to scaffolds and prepared environments. With this, we increased the range of possible spatial configurations that can be taken into account. Learning relations can be performed in regions, network and fluids and are not limited to a specific environment or classroom. This also allows us to resolve incompatible claims about either representational or situated knowledge. As we have learned, it is possible to abandon the notion of knowledge as a separate entity in favor of a performative view where knowledge is embodied, i.e. seen always in connection to who or what is in the process of performing it. Accordingly, learning transfer is made possible not by the transmission and abstraction of knowledge or by invariants among situations, but as a result of translation and the overlapping materiality of social worlds. Lastly, the roles of the teacher and the learner are seen as effects of performed relations rather than being predefined. Thus, we see how it is possible for the agency of the standard teacher to be distributed as educational influence among actors in the prepared environment.

7. Conclusions

As we have seen, a sociomaterial perspective on teaching and learning can be useful in the following ways as a theoretical foundation. First, it allows us to shift from a transmission/construction dichotomy of individual learning to the analysis of participation in material-discursive practices. Second, it helps us to neither neglect nor misplace the participation of mediating materials and scaffolds in sociomaterial assemblages of teaching(-)learning. Third, we can account for multiple forms of knowledge in relation to different spatial configurations, which allows us to acknowledge less teacher-centered and more informal, fluid forms of learning as well. Fourth, instead of hypothesizing learning transfer without transformation and mediation, we are now able to situate learning in a wider range of sociomaterial knowledge-making practices. This, for instance, applies to situations where the contribution of objects is less visi-

ble as well as to practices that are held together by technological devices over long distances.

Yet, as the recent growth of attention may suggest, the agency of things has not started to be a matter of concern since STS scholars began to scrutinize the introduction of digital devices as well as apparatuses of standardization in modern classrooms. Rather, as I have suggested in this article, it started ever since progressive educators talked specifically about prepared environments and included its related assembling efforts into their conception of teaching. This, along with other parallels to past theory, gives rise to a new set of common issues that may broaden the path for future collaborations among researchers in the education sciences and STS.

Acknowledgments

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[1] See Law (2009a) for a sociomaterial understanding of assemblage as "agencement".

[2] The epistemic meaning of 'imaginary' has been discussed by Verran (1998).

[3] Authors such as Allal (2001) propose the term situative learning as an alternative to render visible the participation of more remote objects along "chains of actors" (Latour 2005, 173) distributed in time and space.

[4] This list is not exhaustive, later Law and Mol (2001) also write about the "fire" spatiality.

[5] As originally described by Mol (2002).

[6] As in the word sociomateriality, we may choose to remove the hyphen to distinguish this new interpretation from classic 'teaching' and 'learning'.

L. Centemeri
La permaculture ou l'art de réhabiter [Permaculture or the art of re-inhabiting], Versailles, Quae, 2019, pp. 152
by Silvia Bruzzone

A. Pelizza
Communities at a Crossroads: Material Semiotics for Online Sociability in the Fade of Cyberculture, Amsterdam, Institute of Networked Cultures, 2018, pp. 226
by Polina Kolozaridi

M. Puig de la Bellacasa
Matters of Care. Speculative Ethics in More Than Human Worlds, Minneapolis, University of Minnesota Press, 2017, pp. 280
by Stefano Crabu

Laura Centemeri
La permaculture ou l'art de réhabiter [Permaculture or the art of re-inhabiting], Versailles, Quae, 2019, pp. 152

Silvia Bruzzone *Mälardalen University*

Permaculture has become a buzzword, says Laura Centemeri, the author of *La permaculture ou l'art de réhabiter.* Media, in the last years, have contributed to promote it as a way to trigger a change in the face of environmental and societal challenges. Beyond *les effets de mode*, this book is the result of a long research on permaculture as a political movement. The research is mainly based on the experiences of France, Italy and Portugal. When the author started, in 2013, she noticed the absence of studies focusing on permaculture as transnational movement and of its inscription in the history of organized environmentalism. This absence, she explains, is due to the success of its founders' strategy of presenting permaculture as an a-political movement made of practitioners engaged in the elaboration and experimentation of forms of subsistence capable of minimizing the negative impact on the ecosystems while increasing biodiversity. The intention of the author was then to investigate the contribution of permaculture to the development of an "open ecological society" and in overcoming the modern political vision whereby the social and environmental values are seen as inherently in contradiction.

The book is divided into two parts. The first part is dedicated to the historical development of the permacultural movement. Its origins are situated in Tasmania – cradle of what is considered the first ecological party - in the 70's. The initiators, Bill Mollison and David Holmgren – a professor in environmental psychology and his student – wished to react to the degradation of the environment caused by conventional agricultural. They developed a method based on revisited traditional agricultural practices in order to find ways of satisfying human needs while guaranteeing the regeneration and ecological sustainability of soils and of their fertility. The original name of the method was in fact "permanent agriculture" (Mollison and Holmgren, 1978) which turned into its contraction "permaculture" later on. In order to do that they took inspiration from the ways of working of ecosystems according to a principle of biomimicry. As said their idea was to develop a method based on the technique and not a political movement. Their initiative can be considered part of the back-to-the-land movement, the intent of which was to provide practical tools to promote the autonomy of local communities through an activism grounded on the practice.

The transmission of knowledge – via courses and certification of the training – was, and still is, the structuring element of the movement as well as the organization of international conferences, where the conditions of autoregulation internal to the movement are set.

In the course of the '80s and '90s the first experience grows thanks to the contact with other experiences in Australia, then from the rest of the world, and also with other movements such as the Global Ecovillage Network, the Altermondialist movement and the Transition Towns movement. These exchanges bring to a diversification of practices as well as to different interpretations of the method to include more socio-political approaches to permaculture. The necessity in fact of taking into account different forms of discrimination (in this regard we see the creation of a Black permaculture network) and of vulnerability (for example persons with handicap) encourages the development of more intersectional approaches. What emerges from this first part is a great diversity of experiences, which go under the concept of permaculture and in the beginning of the years 2000 the necessity of founding a new global coherence within the movement is clearly stated.

In the second part of the book, the author analyses the specific type of activism expressed by permaculture and its contribution to the emergence of a "open ecological society". In the author's view permaculture can be seen as an activism of "prefiguration" (Yates 2015) and of the action rather than an activism "of protest". Permacultural design is a central concept and is seen as an individual and collective capacity of elaborating problems and of finding practical solutions in the local context. The principles on which it is built concern taking care of the earth as well as of persons, and fair share (or return of the surplus). Permacultural design is defined by the capacity to take into account the local constraints of the eco-system according to their degree of modificability as resources to build upon. The mostly known method of permacultural design is the one by zones, which consists in organizing the activities in such a way to have a good use of natural and human resources. Even though this idea is very ancient (dating back to Romans' time), what is new is the identification of possible synergies among activities and the mutualization of tools and resources. The observation and imitation of patterns of working of eco-systems is another a key element of permacultural design.

Permaculture is presented not an exact science or an engineering of eco-systems but rather a practical knowledge or, as the author proposes, an art of re-inhabiting a place. The connection with a specific place is in fact central in permacultural activism. The term to "re-inhabit" comes from the American bioregionalism which developed in California in the '70s and which played as inspiration to the founders of permaculture. It designates a way to re-establish a link to a place, which have been damaged and in which the interdependences between the social and the ecological environment become the essential trait. It is about living there and to develop different forms of wealth (ecological, cultural, social, sensorial) which are not intended to profit the single person but to feed the collective well-being. In this regard, the ethic of care – namely earth care – in permaculture refers not only to maintain or to preserve the environment but also to repair damaged soils, to regenerate the life of the soils and to

respect the diversity of its inhabiting beings (earthworms, nematodes, bacteria, fungi, etc.).

According to the author, what characterizes the art of re-habiting embedded in permaculture practices is the identification of a plurality of forms of valuation, which go beyond the market logic and utility. This represents the core of the analysis in which the permaculture experiences are put in the framework of the development of late capitalism.

The training in permaculture, she explains, can be seen in fact as a form of reawakening (*éveil*) to a variety of forms of valuation connected to those places: such as the preservation of species or the production oxygen (universal logic), or the taking into account of human or other species' needs in the conception of a place (goal-oriented logic) or the experience of place through the senses or through contemplation (emplaced logic) (Centemeri 2018). As the author explains the acknowledgement of the heterogeneity of forms of valuation is subversive *per se* as the capitalistic system is based on the progressive expansion of forms of commensurability based on monetarization. The challenge is then to conceive forms of organizations and institutions capable of preserving and developing this plurality and to develop tools capable of taking into account and not to eliminate the problems of commensurability connected to it.

The relationship with the market economy, we understand from this work, is in fact very sensitive in permaculture. Here the author recalls Tsing's beautiful analysis (2015) of contemporary capitalism, which feds on the value, which is created at its margins and which it is appropriated through the supply chain. According to Centemeri, the economies generated from permaculture projects can be described as "peri-capitalist" forms of economic organization (Tsing 2015) in what they remain more or less dependent on the market economy. Controversies on the relationship and compromise with the market economy are in fact present inside the permaculture movement. In this regard, the author proposes to see the experiences, which try to reduce the effect of these logics connected to the idea of "multispecies commons" (Centemeri 2018). These are socio-ecological systems organized on the basis of value logics and practices alternative to the market as they are locally rooted and situated.

An example is the experience of an orange farm in Sicily taking part to a multiplicity of logics of exchange: from traditional market ones to others based on reciprocity and cooperation. Very often, these experiences prefer not to apply for public funding which requires standard principles of production. The aim of multispecies commons is not to generate profits, but to allow a system to maintain itself and to regenerate in time.

Permacultures initiatives, the author observes, are typically to be found at the boundaries between different cultural and political systems (*écotones*) and often in the grey area of regulation. Forms of autocertification of products – like *Genuino Clandestino* – develop in reaction to conventional ones. They have no legal validity and are based on the participation and acknowledgment of its members.

So according to the author, while the idea of earth caring gathers a strong consensus, the notion is not politically neutral. In this regard, even though premature, it is well rooted in democratic values of social justice and emancipation, it can gather also reactionary positions exemplified by some experiences in Italy. The thesis of the book is that, contrary to the affirmation of the founders, permaculture is the expression of a political vision, which can go from an ecological reformist critique to a more radical posture towards the economic system based on accumulation and exploitation. It is also expressed in terms of practices that values the margins and the interstices as spaces of freedom and experimentation "despite capitalism".

This is an interesting and rich analysis of permaculture in its historical development and in what it challenges actual capitalist forms of production and of living in the western world. The research is soundly rooted in the sociology of environmental movements and raises the central question of valuation brought by solutions at the margins of capitalism.

However, if the attempt to show permaculture not as a pure "technique" but a political movement is well achieved, this is at the price of putting the material dimension of the experiences in the shadow. In this sense, readers of *Tecnoscienza* will find that the practice itself lacks in visibility and in concreteness. Since permaculture is proposed as a way of re-inhabiting places through re-invented collaborations between the ecological and social systems, one would have expected detailed accounts of those cross-boundaries interactions. Some concrete and detailed examples of permaculture experiences throughout the text would have been beneficial to the analysis and would have allowed the readers to better understand the variety of solutions, their interconnections with the ecosystems and the implications of the sensitive relationship between the technical and political dimension of the practice which the author significantly points out.

Some methods – like patterns or zoning – are named in principles but we as readers who, contrary to the author, have not attended the training in permaculture have difficulties in understanding what the taught method is really about and also the connections between the "technical aspects" of the teaching and other aspects of the training, such as ethical issues but also for example the relationships with political institutions, funding and regulatory systems.

Some examples of multispecies commons are given at the end of the book but without entering into "technicalities". Synergies between the ecological and social system are evoked but not presented. Even though the intention of the author was to talk about a movement, the reflections on an "open ecological society" imply also an engagement with the complex assemblages and heterogenous interactions (Braidotti 2013; Puig de la Bellacasa 2010) between humans and other-than-humans.

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Annalisa Pelizza
Communities at a Crossroads: Material Semiotics for Online Sociability in the Fade of Cyberculture, Amsterdam, Institute of Networked Cultures, 2018, pp. 226

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"Digital community" is a tricky term. It is used in such a variety of contexts, that both words constituting it had almost lost a meaning. Giant social networking sites like Facebook, influencers with thousands of followers, small activist groups, neighbors, who have a chat for solving everyday issues – this is just a small list of those who can name themselves as participants of an online community. Moreover, not only these groups, but plenty of scholars follow this definition and write about digital and/or online communities and their role, structure, dynamics, etc. It becomes almost impossible to outline the boundaries of the concept. Probably, it is not a term at all, and we should abandon its conceptual roots and speak about all the listed phenomena only nominalistically describing them, shouldn't we? But even when we would try to avoid this word, it will pursue us of speaking about "members" or "participants". So what we need in this situation as scholars is probably not to escape the vagueness of the term "community", but to face it, analyze its controversies and

make the boundaries more evident and clear.

This was one of the challenges taken by Annalisa Pelizza in her book *Communities at crossroads*. The book was written between 2007 and 2009, so now it "can be read under the lens of a double archaeology" (p. 6), witnessing those processes and addressing that period's view backward from both 2009 and the present time. Readers can also enable their own historical approach to analyze the difference between that period and the contemporary times. However, the book is not historical, it is rather conceptual. The author's ambition is more than just the "online community analysis". Pelizza, indeed, "raises questions […] to [...] the foundations of 21st century social theory on the demise of social engagement and sense of community prompted by technological societies" (p. 149).

The book starts with a theoretical investigation of what community is and with the critical review of the myths and foundations of this term. In the empirical part, the author follows the actors working in Linz (Austria) with the archive of the *Prix Ars Electronica*'s Digital Community competition for digital social projects, awarded in the framework of the *Ars Electronica Festival for Art, Technology and Society*. Pelizza undertakes a rather sophisticated analysis of the participants of these competitions, who describe what is their community and why it deserves to obtain a prize. The new understandings of a "community", that Pelizza has found in the fieldwork, are contrasted with the "mythological" history of the term, considered in the first part of the book. In the end, Pelizza focuses on the different approaches to the understanding of action going beyond the very communities she analyzes.

The very problem of community, and how it is connected with action, traces back to Frederic Tönnies' *Gemeinschaft und Gesellschaft*. Pelizza states that the distinction between these two types of sociality created a problematic field for the theorists who followed, and brought, as well, a "dystopic understanding of modern relations in contemporary theorizations of online sociability" (p. 149). Dystopia here is more connected with "society", while "community" is its opposite, that people have lost in the big cities world. Revisiting in this way such foundational opposition, Pelizza's book calls up Bruno Latour's *Reassembling the Social*, which from the very beginning challenges our understanding of social as a part of binary. *Communities at a Crossroads*, indeed, follows the same approach to the ontology as an inseparable, which is part of Latour's (2005) intellectual programs

The literature review which follows has a specific critical aim. Pelizza reconstructs the myth of the community and the internet (and networks before it). She starts with Howard Rheingold's book *The Virtual Community* and treats Rheingold's communities as "rhetorical performative endeavor to merge multiple streams in a coherent account of online sociability" (p. 78). This endeavor seems to be undoubtedly libertarian and based on the mythology that flourished around the online

communities in the end of the 20th century. This mythology is traced back to the cold-war cybernetics and to decentralisation attempts that were inscribed in it. The key features of this particular understanding of communities are the following: treating the internet as an "intrinsically ungovernable machine, the creative coalition between knowledge workers and internet companies, and the spontaneous interactions of internet users producing wealth and political participation as well as empowerment" (p. 147). Pelizza opposes Geert Lovink's "organised networks" to these concepts. However, this term does not itself replace the dominating "communities", rather being a critical alternative to it. .

Looking at the following historical and epistemological changes, Pelizza provides the reasons of the crisis of these myths: geography matters, so that internet results to be more and more controlled and territorialized, the emergence of a creative class related to the coalition between knowledge workers and internet companies crumbled after the Dotcom burst, the idea that digital commons might empower the most disadvantaged ones failed.

Despite these crises, the communities, as concept, persist and are already embedded into those that followed and are still a rather popular approaches to understanding the digital and contemporary sociality. Pelizza focuses on the research projects carried out by Patrice Flichy, Manuel Castells and Barry Wellman. Flichy's project seems to be rather productive from Pelizza's point of view. She praises his reconstruction of the early digital cultures on BBS, Fidonet, etc. and the taxonomy of those, based on three features: "geographical proximity, institutional belonging, degree of face-to-face knowledge"(p. 42). By contrast both Wellman and Castells are treated as proponents of the mythological approach. The main problem is the following one: the two authors become not sensitive to the definition of the group and types of the participants, focusing on the individual action, treating the internet as a space and proposing an essentialistic understanding of the community. However, Pelizza does not introduce here the idea that these different metaphors (like "space" or the very notion of community "community") might themselves influence the research optics (Markham 1998; Van der Boomen 2014).

In order to provide a contrasting fieldwork-based argument, Pelizza maps the words that people use to describe their communities, reveals the relations among them and analyzes the cases more in detail. Then these results are implemented in the theoretical discussion in order to oppose the communities described by the people taking part in them to the "mythological ones". The approach works, for instance, when one "ideal" locality does not turn to be so monolithic, but splits into two of them: the rural and the urban and Pelizza is able to show it. Or, when she is able to brings to the surface the "comparison between HCI, on one side, and sociology of technology and semiotics, on the other side [...][A]ccording to the first approach the subjects of communication pre-exist to the

interactive process, according to the second school subjectivity gets installed through the communicational process" (p. 111). This comparison will be important to further develop the key argument about the definition of technology as mediator or intermediary.

The mapping of the diversity allows to introduce the new criteria to define the online assemblages of software and rules, such as open accounts, regimes of access and visibility that extend the more classical one-to-one or one-to-many. Pelizza also redefines the software as the one that "can articulate the processes whereby a digital assembly is gathered, and different actors are enacted" (p. 143). Such a definition is a step aside from technological determinism and social constructivism, that allows not to lose materiality, as it often happens with the projects on STS and media (see Gillespie, Boczkowski and Foot 2004, as an important endeavor to problematize this).

In the final part of the book, Pelizza suggests a map and some theoretical outcomes. The most evident one is replacing the dichotomy of community/society with a variety of groups and flexible types of sociality. Explaining this variety, Pelizza suggests the new coordinates: stressing "the degree of permeability of the distinction between Addresser and Addressees, Members, and Outside", this map can turn out useful in evaluating the most innovative and progressive digital assemblages" (p. 152).

As an internet studies researcher I find this mapping already useful, but going beyond this mapping, Pelizza provides a theoretical understanding of how the social itself might be thought in a different way. She stresses the double role of the digital artifacts: "the distinction between 'mediation' – a relationship that constitutes actors while taking place – from 'intermediation' – a relationship in which a tool just transports agency from one pre-existing point to another pre-existing point" (p.97). This distinction allows to view different projects and types of social relations and to understand them in a more precise way. This also allows to criticize not only the myths, but also the media and organizations, like Electronic Frontier Foundation (p. 124).

The theoretical ambition of the book is in the end to reassemble the understanding of the social action. Pelizza concludes that "[m]ore than marking the end of social and political commitment, information artefacts, and digital platforms mediate different types of relationships and enact different types of communities. From case to case, information technologies, knowledge, and infrastructures can be conceived of as tools, goals, supporters" (p. 150).

This theoretical claim might seem trivial, as it is rather clear that the material interfaces, platforms and infrastructures are differently participating in the assembling of what we call social. However, if the terms like "software", "technology", "machine" could be re-explained critically at least to some degree, it might be helpful.

The problem I see is that defining the "technological" part of the

community only as mediator or intermediary is again considering as problematic field the social as opposed to the technological. What might be helpful is to bring the same lenses used to look at "community", to look at "digital".

The only further problem with such a program might be a political one. Pelizza's approach is quite helpful in distinguishing communities, which might transform into movements and enable more democratic participation. The reassembled "digital" – i.e. "digital" seen under Pelizza's lenses – might turn on the counterparts of the criticized myths, like the centralization of power and new alliances, e.g. government and business. Then, what we see in contemporary political processes of different countries might be at the same time understood and legitimized.

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M. Puig de la Bellacasa
Matters of Care. Speculative Ethics in More Than Human Worlds, Minneapolis, University of Minnesota Press, 2017, pp. 280

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Few years ago, I got deeply engaged with my colleague Paolo Magaudda in a qualitative research focusing on the development of a grassroots community network (CN) in Italy, originally started in Rome in 2001 under the name of "Ninux.org" to then expand to other Italian cities (see Crabu and Magaudda 2017). CNs are commonly considered as a case of "inverse" infrastructure (Egyedi and Mehos 2012), characterised by being built and self-managed by communities of voluntary people

(hackers, engineering students, and political activists) concerned about the consequences of the neoliberal governance of internet. Briefly, it is about a decentralised network that is fully independent of the internet, particularly respectful of the confidentiality and user privacy, and estranged from the for-profit paradigm.

Unexpectedly, one of the most relevant things we immediately noticed in adopting an S&TS point of view in order to explore Ninux.org everyday life was a sort of "widespread care for everything's intimacy". Thus, the mainstream narrative according to which the source code and the hardware do not seem *matter of care*, revealed itself in all its fallacy. Indeed, in our S&TS exploration within Ninux.org, we directly appreciated multi-faceted caring practices, like the collective responsibility to live within more than human relations. Participating in Ninux.org means enacting a "logic of care" (Mol 2008) for the sake of non-human agents: wireless antennas, which compose an alternative material-semiotic choreography for digital communication, need to be "taken care of". This activity is essential for the development and efficient operation of the network. At the same time, committing to taking care of antennas has both ethical and material implications, as it means participating in and taking care of the collective infrastructure as a (bio)political project.

This way, when I started reading the dense and inspiring book *Matters of Care: Speculative Ethics in More Than Human Worlds*, the narrative of Maria Puig de la Bellacasa invited me to travel back to the CN fieldwork evoking in such a powerful and clear way the generative, political and hybrid nature of care. Better yet, its potential to transform the "present". Ambivalences remain, of course, in the foreground. As Bellacasa nicely put it at the centre of her feminist-positioned argumentation, albeit care is crucial in opening new possibilities for shaping *alterbiopolitics* (see especially chapters four and five) and counter-subjectivisation paths, it may still entail a maintenance work deeply engaged with normative ethics and moral obligations. So, in continuity with the Tronto and Fisher definition of care as "a species activity that includes everything that we do to maintain, continue, and repair our 'world' so that we can live in it as well as possible" (1990, 40), Puig de la Bellacasa proposes an anti-paradigmatic understanding of the concept in terms of practices generated at the interfaces between "labor/work, affect/affections, ethics/politics" (p. 5). In this way, by opening an innovative bridge between feminists and posthumanists Puig de la Bellacasa's "invites a speculative exploration of the significance of care for thinking and living in more than human worlds" (p. 1). Accordingly, in this book, feminist scholarship and S&TS sensibility toward the relational materialism are streams converging in a single river, thus defining a conceptual texture which encourage the reader to take a bold journey to "thinking care as a politics of knowledge at the heart of technoscientific, naturecultural worlds" (p. 15), in which a speculative posture is a reliable compass. A speculative way of thinking that allows Puig de la Bellacasa to avoid normative instances

about care, since this terrain should be intrinsically exposed to be captured within a hegemonic moralising regimen of truth. In so doing the author, differently from other thought of care (see the Introduction), handle this concept as an inspiring tool for enabling a speculative thinking, that is a way to "designing" other possible worlds. Under this perspective, the book, by systematizing seminal articles that Bellacasa published in *Social Studies of Science* and in other journals related to S&TS, deals with ethics, without representing a normative engagement, since it traces a speculative, open-ended conceptual landscape as a way to escape from moralistic ambush, philosophical binaries, or western-based essentialisms.

The first stretch of the journey (part I, chapters 1-3) offers the possibility to cross along a theoretical matrix in which Haraway's (chapter 1) and Latour's works (chapter 2) are mobilized for envisioning an ethics-politics of care. Drawing on Latour's concept of matters of fact as matters of concern (2005), Bellacasa introduces the reader to the notion of *matter of care*, as a way to frame the production of knowledge within a more-than-human process, densely populated with things, devices, and instruments. However, it is through a reconsideration of Haraway's reflection on situated knowledges (1988) that the author makes the reader acquainted with a way of thinking according to which the relational nature of thought and knowledge require care. In this instance, care is an immanent dimension for collective thinking, for dis/entangling global struggles and matters, as well as for thinking care as a political act. This first stretch of the journey is then completed by a nice encounter with the "haptic metaphor" (chapter 3), developed by Bellacasa to challenge the "sensorial metaphor of vision, dominant in modern knowledge making and epistemologies" (p. 97). *To be in touch with*, that is, the sensibility in overcoming conceptual and practical conundrums arising as forms of ethical obligations. And more: to affirm the relationality and reciprocity in taking care of thinking.

What does caring mean when we go about thinking and living interdependently with beings other than human, in "more than human" worlds? This open question is at the centre of the last part of the journey (part II, chapters 4-5), where personal experience within permaculture movements and a critique of the productionist temporalities of technoscience are combined with a feminist perspective to address the concept of care in relation to the outcomes of technoscientific knowledge. By plunging into the permaculture movement, Bellacasa questions the notion of ethical obligation as a way to abiding with a relation ethics oriented at constituting interdependent relations in our ordinary more-than-human everyday life. Thus, soil-human relations are explored in chapter five, where the issue of the temporalities of care is addressed as a means to open living landscapes to emerging ethical and affective ecologies of care, capable of challenging the chronopolitics of hegemonic technoscientific innovation.

At the end of a journey, on our way home, we normally spark a wild-fire of ideas on how our "biopolitics of proximity", the assemblages of socio-technical relations within our *more than human* communities, could be influenced by the journey itself. Now I would like to try to intercept some salient points that may be of interest for S&TS scholars.

First point: more care for thinking and living. The book gives potential conceptual tools for confronting hegemonic, established moral orders, without refusing to consider mainstream notions of care: A help from a feminist perspective, in this case, to overcome *naïf* or elitist approaches and to avoid reductionist simplifications about care. Under this perspective, care is not just a *feminist affaire,* even if feminists offer a strong contribution to the reflections of care, for example by exploring apparently non-gendered practices, such as the production of technical and expert knowledge on soil.

Second point: more care for looking into troubles. This is, I think, a major methodological point, in terms of politics of knowledge, concerning how we – as S&TS scholars – situate our bodies-mind-nature in the context of the research. We can push further with respect to a mere self-reflexivity, by locating our*self*(*ves*), as thinkers and knowledge manufacturers, within a web of care for the (material) consequences of our thinking and knowing.

Third point: more care for engaging. This could be a call for opening a new, more engaged programme in the politics of knowledge production, something that can resound like "S&TS as a more than engaged style of practice". Indeed, in line with S&TS we are well aware of the (toxic) politics and ethics injections within technoscience. However, the stake here is to define a different regimen of possibility to produce knowledge over and within technoscience, one that is able to redesign alternative, more-than-human living landscapes. This also means reopening a dialogue with the '70 and '80 tradition of the radical science studies (e.g. Rose and Rose 1976). Under this light, the notion of care becomes a *dispositif* to configure an "ethical-political practice" and an "affective engagement" within knowledge production about technoscience and nature-culture: transformative knowledge engaged in a troubled contemporary technoscience is actually a matter of care.

Overall, this book represents an embodied transformative project, which asks us – as researchers – to articulate our biopolitical imaginaries into biopolitical action, by refusing the mortifying normative morality, or the neoliberal pragmatism with the aim to develop an affective engagement with and for the human and non-human actors we may meet in our fields. How to translate this points in practice? Is it a speculative commitment, a sufficient style of practices to envision "how things could be different" (p. 17)? Another journey in search for *alterbiopolitcs* needs to be launched soon.

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Essays

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Scenario

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