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Taking Roles in Interdisciplinary Collaborations: Reflections on Working in Post-ELSI Spaces in the UK Synthetic Biology Community

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Based on criticism of the "ethical, legal and social implications" (ELSI) paradigm, researchers in science and technology studies (STS) have begun to create and move into "post-ELSI" spaces. In this paper, we pool our experiences of working towards collaborative practices with colleagues in engineering and science disciplines in the field of synthetic biology. We identify a number of different roles that we have taken, been assumed to take, or have had foisted upon us as we have sought to develop post-ELSI practices. We argue that the post-ELSI situation is characterised by the demands placed on STS researchers and other social scientists to fluctuate between roles as contexts shift in terms of power relations, affective tenor, and across space and over time. This leads us to posit four orientations for post-ELSI collaborative practices that could help establish more fruitful negotiations around these roles.

Keywords: ELSI, post-ELSI, synthetic biology, collaboration, collaborative turn, interdisciplinarity

Introduction

When we open the black box of techno–science – in areas such as synthetic biology, nanotechnology and the life sciences – we see not only practices, materials, engineers and natural scientists, but also social scientists of various kinds, as well as ethicists, policy makers, public engagement practitioners, science communicators, designers, lawyers and regulators. This sociotechnical gumbo is characteristic of the current mixture of well-established and emerging practices of governing science.

Researchers in science and technology studies (STS) are often offered roles in technical projects and as part of scientific research centres, especially in new and emerging fields like synthetic biology and nanotechnology, as well as in environmental and health sciences. The

ways in which STS and other social science scholars are invited into these spaces, and the practices through which such interdisciplinary projects are enacted, have begun to shift. For example, STS researchers have begun working towards more collaborative relations. This paper emerges from our collective experiences in the UK context of being invited to be part of synthetic biology research projects and of how we sought to take more coproductive and collaborative roles in this context.

Novel technosciences like synthetic biology are presented as having huge potential to tackle global challenges but are also understood to present a number of associated "implications." This kind of framing of knowledge making and innovation practices became labelled as the "ethical, legal and social implications" (ELSI) programme. Although it is not explicit, the focus of ELSI is typically on the potential for *negative* implications. Policy arguments concerning the value of involving social scientists and conducting public engagement and dialogue events follow naturally from this "ELSIfication" (López & Lunau, 2012; Marris, 2015; Williams, 2006) and social scientists are often positioned as being responsible for the identification and remediation of potential negative downstream consequences of science. The conclusion that is drawn is that having a social scientist on board will produce public acceptability, improve the competitiveness of grant applications and satisfy ELSI requirements of research funders.

As we describe in more detail in the following section, STS scholars as well as other social scientists have identified a number of problems with the ELSI programme, including the emphasis it tends to place on a simplified, linear model of innovation, the attention given to the outcomes of research and innovation over practices, the assumption that it is easy to classify outcomes as "negative" or "positive", and the distinction between "science" and "society" that it continues to embed. Such dissatisfaction with ELSI has led to the development of a range of more or less explicitly "post-ELSI" approaches to the work of social science in such interdisciplinary contexts. Such work often emphasises the need for deeper collaboration, interdisciplinarity, co-production of knowledge, upstream (or mid-stream) engagement, and real-time technology assessment. In this regard, once inside technoscience – even if invited in through the door of ELSI – STS researchers often seek to negotiate more productive and substantive positions.

However, concerns have arisen that as STS scholars have become more commonplace in sociotechnical fields we have lost our productive critical capacity. There are worries that we have become unable to say "no" to technoscience or to be critical when working with natural scientists and engineers (Nordmann & Schwarz, 2010). Invitations to engage in discussions of the future of technosciences presuppose that the technology will emerge and will necessarily have positive outcomes. At the same time, there are concerns that if we emphasise an "ethics of suspicion" (Fortun, 2005), distrust and antagonism, we are left unable to engage with the often effervescent hubris of promises about future technologies except through the prism of resentment and criticism. However, reflections on our positions within technoscience have often paid little attention to the actual dynamics of these relationships, so that whilst some of the ontological and epistemological challenges of different forms of interdisciplinarity have been mapped (Barry et al., 2008) we have only a few examples of what it is like to work day-

to-day in these spaces (Balmer et al., 2016; Fitzgerald et al., 2014; Rabinow & Bennett, 2012).

In this paper we contribute to filling this gap by reflecting collectively on some of the roles we have taken within the UK synthetic biology landscape. Synthetic biology is an excellent case for such reflections because it is a field in which novel practices of governance are very much entangled with questions about the role of social sciences in relation to the natural sciences and engineering.

This paper emerges from our sharing of experiences with each other and a number of other actors during an ESRC Seminar Series on "Synthetic Biology and the Social Sciences" that ran between 2008 and 2011 (for further details see http://www.genomicsnetwork.ac.uk/seminarseries/). We have continued to meet to discuss our experiences over the subsequent 4 years. We pool our experiences of and reflections on interactions with natural scientists and engineers in synthetic biology – collectively more than 45 researcher years of entanglement – across a range of contexts involving different types of practice, including undergraduate teaching, writing collaborative grant proposals, contributing to the design and implementation of experiments, conducting laboratory ethnographies, and participating in policy forums.

Although the focus of our reflections here concerns our collective involvement in synthetic biology collaboration in the UK, our observations have broader relevance. The collaborative spaces that characterise current work in synthetic biology are, we argue, indicative of an emergent mode of social scientific collaboration apparent across the acad–emy. For example, there are institutionally mandated forms of collaboration around nanotechnology in the US and in Europe (Macnaghten et al., 2005). Ambitious programmes of collaboration are also being developed around climate change, Earth Systems Governance, global change research (Costanza et al., 2012; Hackmann & St. Clair, 2012) and global health research (Molyneux & Geissler, 2008). Moreover, novel forms of collaboration around neuroscience have recently begun to emerge (Fitzgerald & Callard, 2014; Fitzgerald et al., 2014; Rose, 2013). These developments have led some to proclaim the emergence of a "collaborative turn" in humanities and social science scholarship (Fitzgerald et al., 2014). Ongoing shifts in governance and the position of STS in sociotechnical knowledge production have helped to generate an increasingly distinct area of scholarly discussion around collaboration and STS, interdisciplinary entanglements and integration. It is our aim to contribute to this discussion here.

First, we briefly review the emergence and spread of ELSI programmes and examine some of the characteristic discontents that have developed in STS regarding this consolidation, and that point to the emergence of a "post-ELSI" set of practices. We identify a number of different roles that we have taken, been assumed to take, or have had foisted upon us as we have sought to move into post-ELSI spaces. We present these mid-level descriptions alongside ethnographic vignettes from individual experiences of working in synthetic biology to exemplify some of the key elements of these roles. We then argue that the post-ELSI situation is characterised by the demands placed on STS researchers and other social scientists to fluctuate between roles as contexts shift in terms of power relations, affective tenor, and across space and over time. From our consideration of these roles we briefly posit four possible orientations to post-ELSI

collaborative practices that might help in the active negotiation of these movements, both towards post-ELSI spaces and from role to role. We conclude that there is a lasting legacy of ELSI logics and practices that remains obdurate, but nonetheless that there is hope for the future of co-productive collaborative methodologies.

ELSI, its Discontents and the Emergence of Post-ELSI Programmes

ELSI emerged as a programmatic element of the Human Genome Project (HGP) and was thus structurally linked to the development of an ambitious state-sanctioned research effort (Jasanoff, 2007). It was connected to an earlier set of social conflicts over the risks associated with science and technology (for example around pesticides and nuclear technologies) and a concern that the HGP would generate similar controversies. The primary aim of the ELSI project was to mitigate the adverse effects of biotechnology, and thereby ensure that the HGP would be successful, in light of anticipated conflicts. Critically the ELSI programme also acted as a funding mechanism for dedicated research on societal dimensions of biotechnology with between 3–5% of HGP research funding dedicated to ELSI initiatives (Fisher, 2005). More broadly, ELSI research practices have been increasingly folded into what has been referred to as the "new governance of science" (Hagendijk & Irwin, 2006; Irwin, 2006; Kearnes, 2010) and the "Mode 2 knowledge economy" (Gibbons et al., 1994). The emphasis on knowledge production geared towards industrial application and the use of public deliberation to ensure the legitimacy of research agendas has helped to consolidate a dual commitment to "sound science" on the one hand and to social and ethical analysis combined with public engagement on the other (Irwin, 2006). In practice, institutional commitments to ELSI research have also been critical in consolidating research groupings in both the social science and humanities, particularly bioethics, that generally take as their starting point the possible adverse "implications" of technology and the ameliorative role of ELSI approaches (see Fisher, 2005 and Williams, 2006 for further discussion). This arrangement continues to underwrite notions of transparency and accountability in contemporary techno-politics, both as a mark of good neo-liberal governance (Rose, 1999; Lezaun & Soneryd, 2007) and as a conscious performance of accountability and au-thenticity in technological politics (Brown & Michael, 2002; Doubleday, 2004, 2007).

A significant additional factor in the institutional support for the incorporation of social science research and public engagement initiatives into novel technological programmes is the commonplace assumption that the visceral public controversies that surrounded the development of genetically modified crops and civil nuclear power systems were precipitated by broadly "unscientific" public concerns (Wynne, 2006). This deficit model approach underscores commitments to science communication and public engagement alongside the integration of ELSI research into the process of technological development, in areas such as nanotechnology, synthetic biology, neuroscience and so forth. In UK synthetic biology in particular, the "GM debate" was a forceful repertoire, with concerns regularly expressed by research funders and scientists that synthetic biology could become the "next GM", and that the involvement of social scientists would help to prevent this (Marris, 2015). More broadly, there is a conviction that

synthetic biology raises important ethical, legal and social "issues", demonstrated by the large number of reports written on the field – 39 between 2004 and 2011 alone (Zhang et al., 2011). In this regard, ELSI has been both a set of practices used by social scientists but also a logic and political rhetoric adopted by governance actors, scientists, engineers and others to articulate the roles that social scientists can or should occupy within technoscience.

STS researchers, other academic communities, campaign groups and NGOs have all expressed discontent with the ELSI framework, but we focus here on the ways in which ELSI has been understood to limit academic collaborations. Concerns about the development of a commonly accepted policy discourse regarding the early involvement of social scientists through ELSI modes have been voiced in STS and cognate literature. As Williams (2006: 328) has argued, ELSI accounts too narrowly frame the scope of enquiry and are often based on a simplified linear model of innovation pathways and outcomes, which embeds an assumption that

> the societal and ethical implications of new S&T can be 'read off' [the technology] by the application of tools for ethical enquiry.

In other words, ELSI research makes use of a categorical distinction between "the science" and its "implications", enabling what Swierstra and Rip (2007) term a distinctive pattern of moral argumentation, where scientists do science and leave social, moral and ethical questions to experts – ethicists, theologians, lawyers and social scientists. This epistemological gap is enacted in ELSI practices as a division of labour, which reasserts the general assumption that having "read off" the implications of innovations, these can be ameliorated by attending to safety precautions, risk management, and public opinion. These forces of discourse and practice contribute to positioning social scientists in such a way that our role has become characterised as the voice of risk and concern, and we are seen to be joyless and humourless, handwringers, truth-sayers and gate-keepers (Fortun, 2005).

Altogether, these critiques form the basis of an argument for building forms of social science scholarship and public engagement into the development of new technologies that overcome the limitations of ELSI. Current strategies and practices have responded to two key practical and conceptual issues: the timing of interventions; and the need to move away from the applications/outcomes focus. There are a number of approaches here, which represent a response to these problems, including, but not limited to:

i. Upstream public engagement (Wilsdon & Willis, 2004)
ii. Constructive Technology Assessment (Schot & Rip, 1997)
iii. Anticipatory Governance and Real Time Technology Assessment (Barben et al., 2008)
iv. Critical neuroscience as an exploration of coproductive knowledge production (Choudhury & Slaby, 2011)
v. Human Practices as an expressly "post-ELSI" approach (Rabinow & Bennett, 2012)
vi. Responsible Innovation (Owen et al., 2013)

The development of new research protocols and codes of conduct that mandate the inclusion of social science in technoscience research and innovation

practices, variously enacted through the above programmes, speaks to the implicit expectations of contemporary governance and funding regimes, and also to the efforts of social scientists to get involved in scientific practices in more productive ways.

Indeed, we were not compelled to respond positively to the requests that led to us becoming entangled in synthetic biology, but there were several reasons why we did (and continue to) choose to participate upstream in this emerging field. Such spaces provide us with funding and high levels of access to research sites and subjects. At an institutional level, they are often looked upon favourably because they show the "impact" of our social scientific research. Less instrumentally (and bearing in mind that the precise modes of our ongoing work differ in terms of their objectives, intimacy and forms), from our perspective, the hope for such projects is that "working with" scientists and getting further entangled could help to produce novel and more diverse forms of objects *and* knowledge for *all* participants. In this regard, we have – through becoming entangled in these initiatives for interdisciplinary research – sought to produce more collaborative relationships that move towards the co-production of problems, knowledge and innovations.

Given these developments in governance and STS scholarship and practice, we contend that we are already in a fuzzy space between ELSI and post-ELSI, where not only social scientists but also a limited number of policy makers and scientists have begun to talk about collaboration, even if this shift in talk is often accompanied by an understanding that such collaboration might then facilitate better outcomes as regards (negative) implications and the public acceptance of applications. Nonetheless, these entanglements have opened up novel collaborative opportunities that have yet to be reflected on at the level of their routine, everyday practice.

Taking Roles in Interdisciplinary Collaborations

In this section we reflect on a range of roles we have taken as social scientists in the area of synthetic biology whilst working towards post-ELSI collaborative practices. Some of these roles are ones we are keen to adopt and have worked hard to construct; some are roles that others, such as funders and scientists, assume that we play and use to justify our presence; and other roles have been imposed on us and demonstrate the continued legacy of ELSI logics and practices. We describe an array of practices involved in us actively taking-up, negotiating, or being more passively placed in particular roles. Our approach to roles is thus to understand how our attempts at collaboration with colleagues in the life sciences and engineering have been formed and deformed by various practices of making sense of what social scientists may or may not contribute to synthetic biology in the UK. Although our individual experiences have been different, both within our own history of attempts at collaboration and when we compared them with each other, we have found that it is possible to generalise some more abstract roles that we have taken more or less actively within these spaces. A number of elements have been involved in the consolidation of the roles that we describe below, including:

i. scientists, engineers, research councils and other actors' use of ELSI and post-ELSI logics to make sense of and structure our role within technoscience projects;

ii. our own actions, (STS) dispositions and social networks, and how these are responded to by our collaborators; and

iii. the affective, political, symbolic and power dimensions of different contexts of working together.

Although we discuss the roles below as if they were discrete, we are keenly aware of the messy, convoluted and affective nature of our various entanglements with the synthetic biology enterprise, which at times have involved debts, obligations, concerns, loyalties, friendships, contradictions, hopes and fears. So whilst describing these more abstracted roles we also want to point to the schizophrenic negotiation of multiple roles that marks our experiences in synthetic biology. We realise that the messiness of our relations is not distinctive to this field. The anthropologist Diane Forsythe (1999: 22), for example, notes that often in fieldwork "the collapsed roles of participant, observer, critic, employee and colleague collide with one another." Similarly, in categorising the ideal-type roles of field research as "peripheral, active or complete," Adler and Adler (1987: 33–36) comment that "[t]here are times [...] when they overlap, shift in character, or become dislodged." So there is an existing tradition of conceptualising the position of social scientists within sociotechnical fields by abstracting out from the mess of the day-to-day into more clearly defined roles. We want to re-visit these longstanding reflections on the roles of social scientists in the field and update them within the context of contemporary reorganisations of the natural and social sciences, focussing specifically on our attempts at collaboration and the construction of post-ELSI spaces in UK synthetic biology. We ask what work we are doing in these roles and how the roles are constructed from within practices of politics, economics, governance, laboratory work, academic teaching, collegiate relations and so forth. Since we are all involved in different kinds of collaborations and with different groups of synthetic biologists, we cover below many diverse and sometimes contradictory roles, from the overtly instrumental through to the more explicitly antagonistic or to the position of being a critical friend, colleague and co-producer of knowledge.

"The representative of the public"

This role often serves as the initial position from which we are forced to negotiate more substantive relations with the synthetic biology world. In 2007, when one of us attended her first synthetic biology meeting, she was surprised to find her disciplinary affiliation listed as "Member of Society" on the programme. The Research Council organizers clearly assumed that as a social scientist she somehow represented society more than the scientists and engineers at the meeting.

Moreover, our colleagues in the sciences and engineering often approach us as experts in the views of publics, assuming that "public acceptance" and "risk perception" of their technologies and practices are the only crucial issues that need to be addressed. This is also how scientists and engineers often evaluate our potential contribution to grants during the review of funding applications. For example, two of us recently received external reviews of a grant application in which we had contributed a small social science research workpackage as part of the larger scientific grant. The only concern raised in the reviewers' comments about the grant as a whole was that "open discussions with the public [...] must be implemented."

Such assumptions about public understanding then translate into

expectations of what our activities as social scientists should entail. We are often asked by synthetic biology practitioners to deliver "outreach" with the assumption that we can act as a kind of "social lubricant", greasing the wheels of synthetic biology and helping to generate "public acceptability" (Macnaghten et al., 2005). More sophisticated versions of this imagined role are that of "broker", "translator", "mediator" or "facilitator" between scientists and publics. These position us as delivering a service to the science and engineering community, rather than as contributing to collaboration through research activities. Such a role opens up possibilities for action as regards democratic dialogue, but constrains the potential of such action by ring-fencing where this kind of politics can happen as downstream or outside of day-to-day scientific practice. The adoption of ELSI logics by colleagues in the natural sciences and engineering contributes to positioning STS scholars as advisors on engagement, publics and impact, meaning that the possibility for transforming the practices of scientists themselves, or of developing new collaborative practices, is powerfully foreclosed.

"The foreteller"

In order to orient away from the role of representative of the public, we sometimes emphasise that we are interested in the upstream processes and governance of science and innovation. This insistence on being there from the beginning, however, can lead us to be cast in the role of "foreteller", and when combined with the use of extant ELSI logics this can lead to the expectation that our role is to forecast the way (as a linear, singular determination) in which a particular technology will or should develop, and how it will be apprehended by various publics.

STS researchers who promote the use of real-time technology assessment can find themselves cast in this role, which can become re-entangled with the "representative of the public" role when we are asked to predict which particular applications (or words used to describe an application) are likely to be more "acceptable" to "the public". In seeking to succeed in the funding game of science to service the "knowledge economy", "UKplc" and the "European Innovation Union", our colleagues' expectations of us are often shaped towards our capacity to help commercialise their products, which similarly forecloses a range of more collaborative relations.

In a recent round of funding applications one of us was asked to help shape which kinds of technologies should be selected as test cases for the acceptability of synthetic biology by various publics. The ELSI logics made use of in these discussions were sophisticated and indeed his scientific colleagues were open to the idea that different "interest groups" might have different concerns and the team would have to consult with experts in a range of contexts. However, the underlying determinism between technological design and its creation of particular social "outcomes" remained unchallenged. Rather than imagining such a consultation to be part of reconfiguring technological design practices, his colleagues envisioned social scientists in the grant alongside other "public experts" as helping to choose between different applications, essentially foretelling which would cause controversy and be unsuccessful and which stood a better chance of economic and public success.

"The wife"

Many of the roles that we inhabit during our attempts at collaboration have distinctive

affective and power relations, but the role of "wife" is perhaps most exemplary in this regard. Our collaborations often embed a gendered character, built upon the traditional divide between the masculine hard sciences as rational and empirical (Keller, 1982) and the feminine social sciences as emotional and intuitive. Here we identify three central facets of the wifely role: being *dutiful*, *gossiping,* and being a *trophy*.

In terms of the first element, of being dutiful, some of us find that we end up managing the emotional labour of a collaborative project in synthetic biology, by helping scientists and engineers communicate across disciplinary divides (with each other and with us) and by caring for the collaboration as it proceeds. For example, one of us (a female social scientist) was funded as an "administrator", not a co-Investigator, on a research grant, and made responsible for attending to the running of the interdisciplinary project, while substantive matters were overseen by a (male) scientist and a (male) engineer. This type of labour resembles that of wifely domestic work (Oakley, 1974). The gender component is important here, because in this wifely role we are often in a situation of having less power, resources and authority than those with whom we collaborate.

As others have noted, in situations of inequitable collaboration those with less power are required to be empathetic to those with greater power (Graeber, 2006). Moreover, in this inequitable relation we may take on roles in which we must manage our own feelings of resentment, disenfranchisement and subjugation through further emotional labour (Hochschild, 1975). For example, in one research project, one of us found that during an interdisciplinary academic workshop his frequently critical comments regarding the effervescence of synthetic biologists about the positive future impact of synthetic biology on the world began to irritate one of the more senior co-Investigators on the grant. The co-Investigator began to openly display these emotions which served as a censure of the social scientist's role in the workshop. In order to repair the relationship and maintain working practices with the group as a whole the social scientist found that he had to – at least temporarily – affirm the sense that there was much to be hopeful about when envisaging a future for synthetic biology and manage his own feelings of resentment about this inequitable situation.

The second facet of the wifely role is that of the "gossipmonger", with collaborators perceiving us as being essentially interested in "who did what to whom" (one interpretation of our common research methods of observation and interview). It is not unusual for us to be approached at gatherings by synthetic biologists who start conversations with us by invoking a hushed tone of complicity and suggesting they have "gossip" to share. Importantly, the gossipmonger role can serve as a pressure valve for disagreements that erupt between interdisciplinary colleagues – we lend a patient ear and thus help to absorb feelings and diffuse resentments that might be inappropriate to share more publicly. As such, we are often implicitly made use of to manage the social dynamics and feelings of the group.

A third salient wifely role is that of the "trophy wife". This is another category that becomes imposed on us by (some) actors. For example, a (male) social scientist colleague described during one of our seminar series meetings how he was asked at an evening function by a (male) synthetic biologist how it felt to be the research centre's trophy wife. This was meant as a joke, and its resonances

would have been different if the social scientist had been female. However, the connotations of being compared to a trophy wife are clear, since trophy wives have a symbolic function to represent the husband's authority and success. In the synthetic biology configuration, the husband's role is that of entrepreneur, and it is perhaps no surprise that this dynamic has emerged in a field that has so tightly aligned itself with the aims and logics of capitalist innovation. A trophy wife is normally thought to have little merit beyond her physical attractiveness and is drawn to the marriage because of the wealth or the power of the man. She is a stereotyped figure that emerges out of patriarchal assumptions about what women should be. In a similar way, our subjugation in such configurations is based on the sense that we are just a symbol of ethical conduct in the synthetic biology research enterprise; and also perhaps that we are only there in order to get our hands on the scientists' research funds. Indeed, at times some of us have been publicly referred to as "parasites" or "parasynthetic biologists", a less gendered but nonetheless subjugated role. Whilst we find elements of the wifely roles to be undesirable, it is not to say that the more gendered dimensions of care, emotional conduct, ethical virtue and so forth are demeaning for us. Indeed, many of us have embraced these elements of the role and sought to demonstrate their value from within collaborations.

"The critic"

Sometimes we want to play the role of critic, and sometimes this is a role that others assume that we play. There are of course many different ways to be critical. For example, one can be a critic in the negative sense of judging something negatively or finding fault with it (as in "a critic of the government's policy"), or a critic in the sense of judging the qualities or merits of a work (as in being a theatre critic). Forms of critique prevalent in STS include "unmasking" scientific developments by highlighting interests at play (such as gender and capital), and revealing power relationships (Hacking, 1999). Moreover, STS approaches can involve challenging expectations, hubris and hype and thus can appear to be sceptical about the potential of the technology to solve societal problems. This can lead to tensions and misunderstandings with our collaborators, because scientists and engineers, who might not see the social and political dimensions of their practices, can hear this type of critical engagement as seeking to undermine the validity of their work. They might then try to re-frame our critiques as downstream, external "issues", and denigrate them as "merely politics" or "personal opinion" and irrelevant to the actual work of making knowledge and technical objects.

A critical stance can be interpreted as suspicion, distrust or antagonism (Fortun, 2005), denunciation or even resentment (Rabinow & Bennett, 2012), and a critic can be seen as a joyless and humourless "naysayer". Indeed, as noted above, ELSIs are generally only thought of in terms of unintended *negative* downstream consequences. When ethical, social and economic consequences are seen to be *positive*, they are simply described as intended benefits, and form part of the promised future of the scientific endeavour. This narrative organisation of synthetic biology and other emerging fields of research and innovation (with the promises as an inherent part of the technology, and the perils externalized) is an important dimension of the ELSI framework, which shapes expectations about our roles in collaborations. We are seen to be the experts on – and the

voice of – the negative implications. We have commonly observed that natural science and engineering colleagues describe us being "here to make sure we behave ethically" or to "keep us honest." Although such statements might often be accompanied by a laugh or with wry intonation there is nonetheless a clear demarcation being made between who gets to do the work and who is there to observe it. This means that our scientific colleagues sometimes see us as being unhelpfully critical outsiders, as being unable to see the value and good of science and unwilling to celebrate their accomplishments.

When distrust or antagonism builds up from such a disjuncture, the position of critic can start to be seen as undercover agent, acting on behalf of untrustworthy external groups, especially if, as is the case for some of us, we are well connected with NGOs that campaign on synthetic biology. The use of our expertise to inform initiatives led by governments and research funders that aim to support the development of synthetic biology is usually seen by our colleagues as unproblematic (e.g. in the context of the BBSRC/EPSRC Public Dialogue on synthetic biology, or the UK Synthetic Biology Roadmap commissioned by the Department of Business, Industry and Skills), yet is perceived as betrayal when offered to non-governmental actors who are external critics.

"The trickster"

Some STS scholars are attracted to the role of trickster, jester or troublemaker. As Scott (2005: 49) describes, "The trickster is a practical joker, a witty and irreverent being who violates the most sacred of prohibitions." This is different from the "critic" because the point is to question, contradict and destabilize as a deliberate method of engagement by providing an alternative perspective and disturbing engrained ways of thinking. This role is akin to the breaching experiments of earlier social scientists (Garfinkel, 1984), where the drive to disturb is a part of the sociological research process itself. The trickster often makes use of different devices to those common in social science, for example through use of parody and irony, performance and comedy. However, more recent developments in playful and creative methods (Back and Puwar, 2012; Mason, 2011) increasingly draw upon such devices. One vivid example of a trickster intervention occurred at a synthetic biology conference (SB6.0), where two STS PhD students presented a parodical poster that was intentionally blasphemous (Anonymous, 2015). In the synthetic biology community a particular comic book strip, published in *Nature* and produced by leading proponents of the field is often used in conference presentations to signal the fun and "adventure" that comes from working with bacteria in this way. The cartoon depict a young scientist learning how easy it is to work with bacteria when their "DNA parts" are black-boxed and can be obtained from a "catalog" and assembled to "encode your program" (Endy & Deese, 2005). The STS students hijacked this comic book by reworking the images to show a less sympathetic vision of synthetic biology practices and governance. Indeed, the scientists are vilified as cavalier, self-interested and ignorant. But the targets of their trouble-making intervention were not only the synthetic biologists at the conference but also the social scientists collaborating with them, who were pictured dupes, obscurantists and opportunists. The nature of the poster, taking on a parodic form, allowed the students to be frank about their feelings and concerns in a way that might not have been possible in a more traditional format.

However, the "trickster" role raises questions about the extent to which it can be combined with being "embedded" within research groups. Should one seek to criticise from outside or inside? At the same time, playing the role of trickster can be a useful mode through which to engage in debates around this very question since it troubles the distinction between insider and outsider. Trust (or the lack thereof) between colleagues can be made visible through such work, however it also places existing trust at risk and can lead to alienation. Moreover, in order to be productively destabilising it is necessary for those targeted to be open to critique and reflection and to be willing to engage with social scientists taking up the trickster role. Although the SB6.0 poster described above destabilised several of the STS researchers present (including some of the authors), the synthetic biologists at the conference largely ignored it, or walked by and said "cool!", oblivious to the intentions of the intervention (Aguiton, 2014: 453–454).

"The reflexivity inducer"

It has been argued by some social scientists and, to a much more limited extent, by some research funders and scientists, that we should become reflexive partners in scientific collaborations by exploring the normative assumptions that lie behind the choices that are made, or engaging in "opening up", as Stirling (2005) puts it. Such opening up may give rise to broader questions that go beyond the specific technology which is under scrutiny, such as questions about the aims of scientific research, resource allocation and priority setting, as well as what is meant by "good science" (Wilsdon et al., 2005). The aim of this type of role is to attempt to institutionalize reflexivity (Barben et al., 2008), in order to make scientists "more self-aware of their own taken-for-granted expectations, visions, and imaginations of the ultimate ends of knowledge" (Macnaghten et al., 2005: 11). The institutionalisation of reflexivity could potentially enable both scientists and social scientists to imagine their work in ways that are not habitual and familiar.

Opening up is, arguably, best done by exposure to different perspectives, and some social scientists have maintained that seeking to make scientists more reflexive is too internal and not sufficiently encompassing of diverse viewpoints (Mercer, 2012). Exposure to different perspectives is a key aim of participative forms of technology assessment and some STS scholars take up roles in collaborative post-ELSI spaces through the explicit use of this form of expertise. In this role, scholars aim to help uncover social and political contingencies, and to contribute to shaping technological trajectories. However, as is the case for many of the other roles discussed, we often find that these kinds of relationships only gain credence among scientific colleagues and institutions when reframed within promises of "translation" and a contribution to public and/or market acceptance. Moreover, when recast in this way our work to open up science is sometimes reintegrated into the instrumental aim of ensuring a successful – commercial – outcome. As such, our attempts to challenge certain assumptions are legitimated, but other forms of more critical challenge (for example, on the patenting of objects or dominant models of health and medicine) are not taken up.

"The educator"

Most of us have been involved in the International Genetically Engineered Machine Competition (iGEM), in which teams of university students from around the world compete for prizes by creating novel microorganisms using standardised

synthetic biology parts (Frow & Calvert, 2013). Over the past six years, we have variously participated in iGEM as team members, team advisers and competition judges, helping teams to think about the "Human Practices" dimensions of their projects. In some cases we have moved towards more co-productive roles, and in others we have encountered potent forces that resist this reorganisation and retain a distinctly ELSI form.

The educator role differs from most of the other roles described because it is explicitly pedagogical, involving students who may not have yet embraced a particular disciplinary identity, are not yet so imbued with ELSI logics and practices, and are often open to new perspectives (such as those provided by STS). The disciplinary ambivalence that students can sometimes evidence affords opportunities for creative practices that embed reflexive, critical dimensions into scientific endeavours (Balmer & Bulpin, 2013). Both formal and informal pedagogical activities can be relatively comfortable ways of investing one's energy, owing to this possibility for creativity and also the authority that typically accompanies the "educator" role. But there is also a risk that we devote too much attention to engaging with students, at the expense of (often more frustrating) attempts to move more powerful actors towards increased reflexivity.

"The colleague"

In some ways, our research and teaching relationships with scientists and engineers are not notably different from those with our colleagues from the social sciences. We often attend the same seminars and conferences as the synthetic biologists, and find ourselves reading the same literature and asking similar academic questions. Furthermore, we meet not just in synthetic biology venues but also on university committees and exam boards, in corridors and coffee rooms, and even in our local parks. Some of us share supervision of students, teach on each other's courses, and go for dinner at each other's homes. As colleagues, we acknowledge each other as independent academics, although our joint activities are often more concerned with teaching students, achieving concrete tasks or simply having fun than developing a common research agenda or shared knowledge.

Sometimes we are even granted the status of "colleague" during our laboratory ethnographies, a circumstance where one might expect a different power dynamic to prevail. For example, one of us spent a year in a US synthetic biology lab, and was treated as an equal throughout – given desk space, and expected to contribute to lab meetings and discussions as any other member of the group. Working with research teams (either in an ethnographic capacity or as a co-investigator) means that we often work alongside students, post-docs, junior and senior academics, and changes within the team can affect the roles we play with different members of the group. We can be sad when group members leave, happy when a post-doc gets a permanent post, keep quiet when internal team tensions arise, or be supportive when inequalities are on display. The affective or emotional dimensions of different contexts are important in making different roles available and closing others off and so can powerfully shape our ability to move from role to role. Indeed, when we are colleagues it can sometimes be harder to navigate into other roles, for example in being a critic or trickster. On the other hand, developing a collegial relationship can produce trust and openness in ways that can then make it easier to co-imagine and practice "co-producer of knowledge" roles.

"The co-producer of knowledge"

In many ways the "co-producer of knowledge" role remains an aspiration in our collaborative relationships. In this role we imagine ourselves contributing directly to collaborative knowledge production through our own forms of expertise in STS, sociology, technology assessment, cultural studies and so forth. For example, when Rabinow and Bennett (2012) first started working at Synberc they were excited by the prospect of a co-production among disciplines and perspectives. Operationalising this goal, however, is often not straightforward, and that particular collaboration did not work out as originally hoped.

Nonetheless, some of us have had positive experiences in this area. For example, three of us have participated in a project exploring the use of synthetic biology in the context of water engineering. Our STS outlook ended up playing a role in shaping how the problems of water engineering were conceptualised. By exploring different ontological articulations of bacteria involved in engineering contexts, and by investigating what our colleagues understood to be a "barrier to innovation," we were better able as a group to envisage how synthetic biology solutions might need to be tailored to specific contexts of use. At the same time, this research contributed to STS analyses of the multiple ontologies of objects (Balmer & Molyneux-Hodgson, 2013) and performativity and innovation (Molyneux-Hodgson & Balmer, 2013). To give another example, in the Synthetic Aesthetics project in which two of us participated, a sense of genuine co-production of new knowledge at the intersection of disciplines emerged (Ginsberg, et al., 2014). Perhaps one reason for the lively and productive nature of this collaboration between artists, designers, synthetic biologists and social scientists was that no one group had epistemic authority over the direction of the research. Nor was there a sense that the social scientists had been "tacked on" to the project in an instrumental manner. Both of these projects have provided firm starting points for further and ongoing collaborations.

Moving between Roles: Playing the Chameleon

Our experiences of these roles differ widely over time, across projects and spaces, and between us as individuals. Some of us feel that we are under pressure to adopt the more instrumental roles described above (such as delivering public acceptance), and that roles of the "co-producer" variety have no apparent relevance for scientists, engineers and funders, and thus become impossible to negotiate. But even if it is for instrumental reasons that scientists initially forge collaborations with us, we have found that expectations can change over time and as we adopt alternate roles.

This brings us to one critical dimension of the contemporary post-ELSI experience, namely the practice of having to move back-and-forth between roles and "play the chameleon." In other words, various positions and actions become differentially possible across space, types of engagement and over time. It is far easier to experiment with co-production and induce reflexivity in the lab with a group of talented undergraduate students in an iGEM team than it is with a group of established professors of engineering and science during a meeting with cabinet MPs, civil servants and corporate executives. In this latter context the ELSI discourse becomes more potent. In this regard, when working with colleagues who are open to co-production it can nonetheless be extremely difficult to maintain such openness

when entering spaces where disciplinary authority becomes far more potent, for example as the political valence of the space changes. As some roles become more difficult to create, others become more difficult to resist.

The goals and aspirations of collaborators are often not mutually shared. STS scholars may have different interests and goals when entering collaboration than do colleagues in other fields, whether they are other social scientists, natural scientists, engineers or designers. Of course, having different goals can contribute to the success of a project as different members bring different expertise and outputs to interdisciplinary work. Disagreements about the purposes or goals of an activity, event, or project can be productive, but they can also create an obstacle to building trust between collaborators or damage the trust that has been built. This is not to say that goals have to be shared, but rather that the difference in goals connects to the affective dimension of collaborations, and that together these contribute to opening up or closing down possibilities for action and so to the (de)formation of collaborative relations.

In our experience, the initial organisational and strategic framing of a research project has proved particularly important in shaping the kinds of collaborative spaces which allow certain roles to flourish and multiply over time. For example, the egalitarian and open structure of the Synthetics Aesthetics project mentioned above created a space where it was possible to embrace the sometimes more difficult, risky dimensions of playing the trickster experienced in other projects. This is evidenced in the creative and diverse ways in which natural scientists, artists and social scientists worked collaboratively to play with the limits and visions of synthetic biology. For example, Christina Agapakis (synthetic biologist) and Sissel Tolaas (scientist, linguist and artist) created "human cheese" by culturing microbes harvested from people's skin. The trickster role also enabled and in turn was nurtured by the adoption of other roles that were permitted within this space, namely those of reflexivity inducer and co-producer of knowledge.

Those of us who have been welcomed as colleagues on research projects and within scientific departments and laboratories have also found that the expectation of equality that can accompany the notion of being someone's colleague opened up spaces where we could more easily adopt roles as educators and reflexivity inducers. For example, by being invited to participate in weekly lab meetings, we have found places to introduce synthetic biologists to some ideas from STS and to use these concepts to encourage them to think about what they did day-to-day. These roles have often quietly opened doors for us to take up other interesting and productive positions within these collaborative interactions.

Conversely, the type of role we are expected to play can be rigidly proscribed from the outset, leaving little room to develop the more collaborative, co-productive kinds of roles we seek to inhabit. In particular, the organisational classification of our role can be very restrictive and can set up notably different power relations such as in one author's experience of only ever being invited to participate in one particular research group when there was a public engagement event being organised. The group in question had not collaborated with a social scientist before but had funding for synthetic biology research that required them to do some public engagement events. This meant that every now and again over a few years the social scientist

was asked to fill roles that were attuned to these more public spaces. Barriers to developing a more substantive relationship involved differences in institutional affiliation, a lack of funding to support such work, and – being on a temporary contract – unknowns regarding the future of the relationship. At the same time, he was engaged with colleagues elsewhere to develop a funding application that would involve more collaborative entanglement. When the application was successful the attempts to move from public engagement facilitator to co-producer of knowledge with the previous group fizzled out as his time became more constrained, the enthusiasm waned, and his responsibility to the new project took precedence.

Other examples of "playing the chameleon" can take place over a very short period of time. In one meeting, one of the authors of this paper experienced being positioned as a trophy wife with a tick-box role in representing the social and ethical dimensions of synthetic biology, a representative of the public, and a foreteller of public attitudes towards synthetic biology all in one meeting! Further, in pointing to some of the limitations and assumptions being made in the discussion she found her roles proliferating into trickster and critic and occasionally morphing into positions where more co-productive and reflexive work could be done. Moving between roles within a given situation can thus be something that social scientists strategically use to find a position from which to voice substantive critique. Trying out different roles, or adopting one (trophy wife) in order to move into another (representative of the public) and then another (critic) is a common feature of negotiation through the current uncertainties in status that social scientists have within attempts at post-ELSI collaboration.

Others among us have experienced similar transitions between critic, public representative and co-producer of knowledge and have found these different roles to be generative of sometimes surprising power dynamics. For example, one author found that he could be quite easily dismissed when he inhabited a critical role as his scientific collaborators could ignore him as merely a naysayer who was trying to burst the bubble of synthetic biology promises. Contrarily, he found that "representing the public" was sometimes quite a powerful position because scientists and engineers, through their imaginaries of the public and the future, tended to invest the public with the power to derail a whole programme of research. In this regard, the role was actually sometimes a useful way to have legitimate concerns about sociotechnical practices heard in a context that was otherwise quite closed to friendly criticism. Of course, that role also became a little difficult to then divest since it had been adopted quite forcefully. So moving from role to role and playing the chameleon invokes shifting power relations, and indeed can be one response used by social scientists to a given set of power relations as they are encountered in a specific space. But of course adopting roles that can be more useful or comfortable within inequitable power relations does not necessarily help to create ruptures and resistance to those power relations and may – in the longer term – have the effect of further consolidating inequities.

Lastly, although being a co-producer of knowledge is often what we aspire to do in our collaborations, this role can itself become problematic when we find ourselves contributing to an element of the project that we remain uncomfortable with. This raises questions as to what extent we can withdraw or distance ourselves from positions that we have ended up in,

particularly when we have fought for them, but also when we have inhabited them less intentionally. Moreover, synthetic biologists appear to be under less pressure to negotiate their way through various roles in order to maintain the collaboration. Certainly, they must adopt different roles as they move through power relations in governance, industry, laboratory and university hierarchies and so forth. However, these have more to do with the everyday nature of scientific practice than they do with the development of post-ELSI collaborations. In this regard, STS scholars, as well as other social scientists, are generally the ones who take or are forced to adopt the role of "chameleon" in order to maintain relationships. Synthetic biologists less visibly, so far at least, adopt this chameleonic role in order to support experiments in collaboration. Power relations in the post-ELSI space thus place different weight on participants to ensure their continuation or open them up to change. So whilst there are opportunities that emerge from skilfully negotiating from role to role, the option to divest oneself of this requirement comes with a high price, in terms of one's career, academic standing, wasted time, emotional labour and so forth.

This analysis suggests that post-ELSI scholarship has to take into account various elements involved in adopting roles within collaborations, including power dynamics and affective and emotional relations. We should more thoughtfully attend to how these elements affect the roles that individuals can or have to play in interdisciplinary technoscience and with what implications for knowledge production and innovation practices.

We think that there are some lessons to be learned from our experience. However, there cannot be hard and fast rules given that the contexts vary so powerfully, the roles one adopts may shift frequently, and because what is at stake is the creation of relationships of trust and understanding, even – perhaps especially – in the face of unshared goals and inequitable power relationships. Therefore, rather than offering a list of rules for those seeking to move towards post-ELSI spaces, we now briefly propose four orientations to post-ELSI collaborative practices that we believe can be productive when talking about and practicing collaborative relationships involving STS, natural science and engineering.

Orientations for Post-ELSI Collaboration

Collective Experimentation: As post-ELSI spaces develop we have to experiment more with forms of interaction through which social scientists, natural scientists, engineers and other actors might work together. We have to find ways in which our forms of expertise can be part of mutually productive collaborative relationships. This means we need to do experiments collectively and also to experiment in making collectives. Much like experiment in science, we must be adventurous and playful, willing to explore the unknown, tinker with our practices and be resilient in the face of failure.

Practising Collaborative Reflexivity: As post-ELSI spaces emerge there are perhaps renewed opportunities for experimentation with forms of reflexivity. STS researchers have discussed reflexivity in myriad ways since the field's inception, although there has been more talk than practice. Since existing structures of political power and governance of science both constrain and enable different possibilities for collective experimentation, we must be reflexively attuned to how our collaborations are

enacted in day-to-day practice and how they are awarded credibility or not. Reflexivity itself should be collaborative; it should involve scientists and engineers together with STS researchers (and others) in its practice. This can help to free the STS researcher from a position of moral judge and naysayer and implicates everyone in working towards improved relations.

Taking Risks: Some positions involve more risks than others. Ongoing collaborative relationships require that we move from role to role, sometimes shifting into more critical or antagonistic positions, other times into more coproductive and collegial alignments. The various roles one can take involve different levels of risk and different kinds of vulnerability. Nonetheless, we believe it is vital that we take risks and experiment with form-giving and reflexive collaboration in order to produce novel post-ELSI entanglements. However, experiments often fail. We have to be comfortable with failure, but also acknowledge that failures will have different affective dimensions and impact differently on careers depending on seniority, gender, discipline and so forth. Opening-up these differences to discussion might help to ensure that we are better prepared for the failure of our collaborative experiments.

Opening Up Discussions of Unshared Goals: We have to negotiate expectations around what we hope to achieve from these collaborations and how this might differ for our engineering and science colleagues. This can often mean very frank discussions that – although they do not produce shared goals – can produce shared interests and more mutual understanding. We might not have to have shared goals but we might still have to be honest about this. Speaking honestly with each other and seeking to negotiate mutual understanding without demanding mutual goals can be difficult and so place the collaboration at risk of failure. Some argue that the answer lies in being comfortable with a degree of concealment (Fitzgerald et al., 2014). However, when working in long-standing collaborations and moving from role to role different positions may make concealed goals and dispositions difficult to maintain. So although frank discussion can itself be risky it is perhaps worth this risk if we are to move towards more interesting and productive relationships in the longer term.

Conclusion

Ethics, under the banner of ELSI, has been predominantly considered as a downstream, object-oriented enterprise concerned with "reading off" the ethical from the technical. We have described how ELSI logics act as a force in the shaping of scientists' invitations to us to collaborate and how they are used to position social science in relation to the research and innovation endeavour. Indeed, they are so deeply embedded in scientists' and funders' understandings of "the social" that they often become the most significant force against which our work to negotiate a deeper collaboration must be orientated. Like many other STS scholars, we have endured frustrations when struggling to negotiate acceptance of our expertise when it is unwittingly repositioned by our colleagues or actively resisted. This requires us constantly to reflect on the distance we are prepared to go in negotiating research relations and working towards collaborations in more intransigent spaces, and points to the difficulties experienced when colleagues are reluctant to try alternative forms of collaborative practice.

Set against the background of ELSI, its critique and the emergence of post-ELSI collaborative relationships, we have discussed a range of different roles and some of the elements involved in making these roles more or less comfortable, and more or less difficult to adopt. The collation of our individual experiences in working towards collaborations into these descriptions represents one of the primary contributions of this paper. Moreover, we have opened-up considerations of power and the affective and political dimensions of collaboration, some of which become particularly acute when considering the contemporary requirement for social scientists to move from position to position and role to role to help keep collaborations working. As such, we have provided a novel argument regarding the contemporary movement towards interdisciplinary collaborations between natural and social scientists, one that highlights how social scientists are expected to "play the chameleon" within changing networks of power, affect and politics.

Although we have argued that our relationships with colleagues in the natural and engineering sciences must often be developed from within or in dialogue with the stubbornly resilient framework of ELSI, it is also possible to move towards post-ELSI practices that offer far more in terms of their collaborative promise. Finally, we have briefly outlined some orientations that might prove fruitful for others seeking to negotiate different kinds of relationships and we believe that there is much hope for the creation of productive collaborative forms.

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The Co-Construction of Energy Provision and Everyday Practice: Integrating Heat Pumps in Social Housing in England

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Challenges of energy security, low carbon transitions, and electricity network constraints have led to a shift to new, efficient technologies for household energy services. Studies of such technological innovations usually focus on consumer information and changes in behaviour to realise their full potential. We suggest that regarding such technologies in existing energy provision systems opens up questions concerning how and why such interventions are delivered. We argue that we must understand the ways by which energy systems are co-constituted through the habits and expectations of households, their technologies and appliances, alongside arrangements associated with large-scale socio-technical infrastructures. Drawing on research with air-source-to-water heat pumps (ASWHP), installed as part of a large trans-disciplinary, utility-led research and demonstration project in the north of England, we investigate how energy services provision and everyday practice shapes new technologies uptake, and how such technologies mediate and reconfigure relations between users, providers and infrastructure networks. While the installation of ASWHP has led to role differentiation through which energy services are provided, the space for new forms of co-provision to emerge is limited by existing commitments to delivering energy services. Simultaneously, new forms of interdependency emerge between users, providers and intermediaries through sites of installation, instruction, repair and feedback. We find that although new technologies do lead to the rearrangement of practices, this is often disrupted by obduracy in the conventions and habits around domestic heating and hot water practices that have been established in relation to existing systems of provision. Rather being simply a matter of increasing levels of knowledge in order to ensure that such technologies are adopted efficiently and effectively, our paper demonstrates how systemic arrangements of energy provision and everyday practice are co-implicated in socio-technical innovation by changing the nature of energy supply and use.

Keywords: air source heat pump, diffusion, innovation, social housing, social practices, socio-technical systems, smart grid

Introduction

The United Kingdom, alongside other European countries has set ambitious long-term CO_2 reduction and renewable energy targets, which have become key drivers in shaping energy policy. The UK government aims to cut greenhouse gas emissions by 80% from 1990 levels by 2050, with implications for energy supply and demand. Increasing renewable sources of energy is a key element of the UK strategy. Future projections of carbon emission savings rely on widespread uptake of a range of low carbon energy sources (DECC, 2013) including small scale, low and zero carbon micro-generation heat technologies (HM Government, 2009; EST, 2007). Heat pumps are a key technology for delivering low-carbon heating (DECC, 2011; Spiers et al., 2010). European Union policy encourages the wider uptake of heat pumps by including them in a list of renewable technologies designed to meet national obligations to increase the percentage of heat generated from renewable sources (EU, 2009). For the UK this entails a shift away from dependence on ubiquitous gas powered domestic central heating to technologies powered by new forms of low carbon electricity. However, there are uncertainties over how this new electricity system can be realised, and how consumers might relate to unfamiliar heating technologies. Current understanding of how novel low carbon thermal technologies become integrated into homes is limited (Wrapson & Devine-Wright, 2014).

This study aims to increase under–standing of how low carbon heating technologies are accommodated within the household and how heating practices might change to realise policy objectives. Further understanding this process requires examining how provision and use of energy services through domestic practices are co-constituted and assessing their potential for change. Elements of provision and of practices vary across countries and sometimes regions within countries. Here we draw on initial findings from the Customer Led Network Revolution (CLNR) project, an industry-led and regulator-funded trans-disciplinary project located in the north east of England involving qualitative research conducted among participants recently fitted with an air-source-to-water heat pump (ASWHP).

This paper argues for a perspective that unites all elements of energy production, distribution and consumption under the single concept of *a system of provision*. We explore an example provided by empirical research on heat pump installations in social housing, an emerging market and focus of activity. We illustrate the dynamics entailed in a whole systems approach by exploring the ways that ASWHP installations in existing housing schemes open up the order of energy provision and consumption, creating and closing down spaces for alternative modes of consumption based on the co-provision of services on the one hand and reconstituting interdependencies between users, providers and systems on the other. These dynamics of co-provision and interdependence respond to alterations at different points in the system. We focus on changes that occur through technological innovation in the form of ASWHPs, and the ensuing adaptation of practices in which they constitute a material element (Shove et al., 2012: 32). We also consider the wider perspective and how its formation is reconfigured or reinforced.

An overview of the main domestic heating technologies in the UK is followed by a summary of the factors underlying adoption and diffusion of heat pumps, and review of previous studies on retrofitting heat pumps in existing housing. The second section of the paper outlines how

implementation of low carbon technologies in domestic spaces is positioned to meet UK objectives to achieve a decarbonised energy system and how such innovations are conceived in technical and social terms. In the third section, we introduce the project and our methods. The fourth section of the paper considers how ASWHPs might reconfigure and reinforce systems of energy provision. In section five we examine the extent to which ASWHPs are 'domesticated' within practices, and conclude by reflecting on the implications of our findings.

The Context: Heating Systems in the UK

Around 20.5 million dwellings in the UK (90% of the housing stock) have central heating as their main heating system, 1.6 million dwellings (7%) have storage heaters, and 0.7 million dwellings (3%) have room heaters. In 2011, the proportion of households using gas for their central heating was 91%, with less than 1% solid fuel, just 2% electricity, and oil 4% (DECC, 2013a). Wet-based gas central heating dominates space and water heating, in the main areas in which gas is available (Hoggett et al., 2011). Direct electric heating or night storage technologies are also reasonably prevalent, with households in remote locations less likely to have access to gas than those in urban areas (DCLG, 2013). Some households make use of coal, wood and other solid fuels to provide heating services. Modes of operation of ASWHPs differ from these conventional heating systems (Table 1). Thus, for many UK households, ASWHPs represent a changed experience of heating provision that demand new skills (Gram-Hanssen et al., 2012; Heiskanen et al., 2014).

In the UK, heat pump technologies are closely tied to the synchronous development of smart grids and de-carbonisation. In this context, government policy identifies ground and air source heat pumps as a means to reduce carbon intensive technologies for space heating (e.g. BERR, 2008; DECC, 2011; HM Government, 2009) though their adoption lags behind mainland Europe and North America, with the uptake of ASHP particularly sluggish (Singh et al., 2010). Financial support for the installation of heat pumps is available from the government to homeowners and landlords through the Renewable Heat Incentive, launched April 2014 (DECC, 2013b), replacing the Renewable Heat Premium Payment (RHPP), and promoted by quasi government intuitions such as the Energy Saving Trust.

Uptake of Heat Pumps

Different authors highlight different 'factors' to explain the uptake of heat pumps in a particular context (e.g. Fawcett, 2011; IEA, 2010; NERA & AEA, 2009; Singh et al., 2010). These include: climate, government policy on energy and environmental issues, energy prices, availability of competing energy sources, electricity supply and generation characteristics, housing characteristics, history, geography and geology. The market penetration of heat pumps in the UK remains small. Heat pumps providing both space and water heating are most popular (Roy et al., 2008), with the majority located in new residential buildings and in dwellings without mains gas (EST, 2010). This ostensibly makes optimum gains in domestic energy efficiency by replacing electrical heating systems.

Given the large stock of older, thermally inefficient dwellings, the UK retrofit market presents significant potential and challenges. Limitations to the widespread adoption of ASWHPs identified in previous studies are: initial capital costs (compared to common alternatives), underperformance, technical difficulties, preferences for other familiar and reliable technologies, inertia, a small-scale and fragmented heat pump

Table 1. Comparison of main UK domestic heating and principles of use

Heating system/ fuel source	Principles of use				
	Infrastructure system	**Mode of operation**	**Control**	**Advantages**	**Limitations**
Gas	Piped direct to houses on gas grid	High running temperatures	Programmable thermostatic/ timer control – suitable for intermittent heating	Rapid response Control of individual radiators using Thermostatic Radiator Valves (TRV)	Dependent on access to gas supply network
Electric night storage	Uses off-peak electricity (Economy 7 or Economy 10 tariff)	Heat is stored in ceramic bricks and released gradually during the day	Individual control Manual control/ adjustment	Supplementary heating may be required Dry heat Economic, if operated correctly (off-peak, cheaper electricity)	Limited control over level of heat and when it is dissipated Increase in airborne dust when using fan to circulate heat
Direct electric	Requires input of mains electricity	Delivers localised heat	Individual control Manual control/ adjustment	Responsive Provides cosy 'glow'/focal point	Manual operation
Oil	On site oil storage tank required	High running temperatures	Same controls as for gas heating	Rapid response Suitable for intermittent heating	Requires pre-ordering and delivery of oil
Solid fuel e.g. coal, wood	On-site storage required	Burning coal, wood, biomass in open fire, solid/multi fuel heater	Lack of thermostatic/ timer control	Provides cosy 'glow'/focal point	Requires pre-ordering and delivery of fuel 'Dusty' Requires effort/less convenient than other forms of heating
ASWHP	Requires input of mains electricity	Lower operating temperature than gas or oil fired central heating	Programmable thermostatic/ timer control Unsuited to individual control of radiators using TRV	High efficiency, if designed, installed and operated correctly	Efficiency depends on correct set up e.g. supply temperature Not suitable for fast heat up Requires longer running periods than gas/oil systems to achieve equivalent level of comfort Noise during operation of fan

installer industry, skill deficits, and other institutional barriers (Bergman, 2013; Caird et al., 2012; Element Energy & NERA, 2011; EST, 2010; Fawcett, 2011; Hoggett et al., 2011; Pither & Doyle, 2005). Installing heat pumps in existing dwellings requires the retrofit of energy efficiency measures, and the transition to a low temperature heat distribution system, which could be both costly and disruptive to install in an existing property–particularly where underfloor heating is required (Fawcett, 2011). ASWHPs are smaller and cheaper, with lower installation costs than GSHPs, and better suited for the retrofit market. The focus of this paper is on retrofitting ASWHPs in social housing as an emerging market segment. Social housing accounts for 5 million dwellings, or 18 per cent of the UK housing stock (ONS, 2014). Social housing providers are installing heat pumps to reduce heating bills (Bergman, 2013). However, several studies and reports on householder experiences (e.g. EST, 2010; Hoggett et al., 2011; Stockton, 2011) identify problems around installation and use of ASWHPs, particularly amongst social housing tenants.

Table 2. Heat pump retrofit studies

	Year	Units/participants	Heat distribution system/DHW	Method
UK studies				
Pither & Doyle UK	2005	GSHP (56) ASWHP (1) 57 units in 7 case study projects, of which 35 are retrofit Social housing tenants (54) Owner-occupiers (2)	Various configurations, mainly DHW and radiators for space heating	Survey (18 resp.) of which 16 social housing tenants, and 2 owner occupiers
Energy Saving Trust & Scottish Government UK	2008	GSHP (22) ASWHP (34) Social housing tenants (56) Owner-occupiers (31)	Various configurations, mainly DHW and radiators	Daily diaries, survey (75 resp.) and telephone interviews
Energy Saving Trust (Phase 1) UK	2008–2010	GSHP (54) ASWHP (29) Mixed: Owner-occupiers and social housing tenants (83)	Heating (21% UFH; 14% Mixed; 64% radiators) and DHW (73%) [1]	Detailed monitoring (83)
Boait et al. UK	2011	Social housing GSHP (10)	DHW and radiators	Detailed monitoring (10)
Stafford & Lilley UK	2012	Social housing GSHP (10)	DHW and radiators	Detailed monitoring (10) and social/behavioural investigations
Caird et al. UK	2012	Owner-occupiers (48) Social housing tenants (30)	Various configurations, mainly DHW and radiators (36); DHW and underfloor heating (17)	In depth user survey (78 resp.); focus group with social housing tenants
Owen et al. UK	2012	ASWHP (12) Owner-occupiers (12)	Space heating (not specified) and DHW	Interviews with: owner-occupiers (6); programme managers (2); surveyors/ installers (4)
Energy Saving Trust (Phase 2) UK [1]	2010–2012	Mixed: Owner-occupiers and social housing tenants (44)	Various configurations, mainly space heating and DHW (33)	Detailed monitoring Face to face and telephone interviews (35)

Table 2 cont.

	Year	Units/participants	Heat distribution system/DHW	Method
Other European studies				
FAWA, Switzerland	1996–2003	221 (existing 40%) [1]	Space heating (54% UFH) and 50% DHW [1]	Detailed monitoring; survey [2, 3, 4] New and existing buildings
Stenlund & Axell, SPTRI, Sweden	2007	GSHP (5)	Space heating and DHW	Detailed monitoring (5 dwellings); survey (251 resp.); interviews (25)
Lahr, Germany	2009	ASHP (12) GSHP (13)	Unknown	Detailed monitoring [2]
Elvari Finland	2010	ASHP (78)	Unknown	Unknown [6]
Russ et al. Fraunhofer ISE Germany	2010	ASHP (36) GSHP (36)	Heating (3% UFH; 26% Mixed; 71% radiators) and DHW (100%)	Detailed monitoring [2, 5, 7]
Pedersen et al. Danish Technological Institute Denmark	2012	ASHP (12) GSHP (138)	Heating (16 % UFH; 70% Mixed; 14% radiators) and DHW (100%)	Detailed monitoring [2]
Gram-Hanssen, Christenson & Petersen Denmark	2012	ASHP (481) Owner-occupiers	Space heating and cooling	Survey (481 resp.); electricity consumption data (180 households); face-to-face interviews (12)
SEPEMO Austria, France, Germany, Greece, Netherlands, Sweden	2009–2012	ASHP, ASWHP, GSHP (52)	Space heating and DHW	Detailed monitoring (44) of new and existing dwellings [8]
Winther & Wilhite Norway	2014	ASHP (22) ASWHP (2) GSHP (4) Owner-occupiers (27) Tenants (1)	Unknown	Face-to-face interviews (28)

[1] See also Bradford J & Byrne T (2013) The UK heat pump field trial: findings from phase 2. ECEEE 2013 Summer Study. The European Council for an Energy Efficient Economy (ECEEE).
[2] This study is not available in English. Details obtained from Gleeson C P & Lowe R (2013) Meta-analysis of European heat pump field trial efficiencies. Energy and Buildings 66: 637–647.
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There is a risk of heat pumps not delivering expected energy or carbon savings (Bergman, 2013; Caird et al., 2012; Fawcett, 2011; Wrapson & Devine-Wright, 2014). A further concern is that electrification of heating (and use of heat pumps for summer cooling) will contribute to increases in residential electricity demands, putting additional strains on distribution networks (Element Energy & NERA, 2011; Hoggett et al., 2011; Skiers et al., 2010).

Heat Pumps in Existing Housing: Performance

This section reviews available published studies on retrofitting heat pumps in existing domestic dwellings (summarised in Table 2). Many studies focus on monitoring efficiency and technical factors affecting performance (e.g. Boait et al., 2011; EST, 2010). There is little available information on householders' experiences and practices of using heat pumps, despite users' affecting heat pump efficiency (DECC, 2013c; Miara et al., 2013; Stafford & Lilley, 2012). The main UK evidence comes from the Energy Savings Trust (EST, 2010, 2013) and Caird et al. (2012), the largest UK heat pump study and comprised of both owner-occupiers and social housing tenants. The study by Owen et al. (2012) includes interviews with 12 owner-occupiers, of which five participants were retired, and three householders had significant health problems. The remaining UK studies in Table 2 are predominantly concerned with social housing. It was not possible to determine tenure in all other European studies. Previous studies (Caird et al., 2012; Pither & Doyle, 2005) indicate that social housing residents were more dissatisfied with their heat pump systems than private householders, particularly with regard to running costs, technical support and comparison with their previous heating system. In the survey by Pither & Doyle (2005), 33% of respondents gave the highest score for effectiveness of heating. However, 17% rated heating as average and 2 participants gave a very low score. Provision of hot water rated more highly than heating. Forty per cent of occupants thought more instructions were needed, and 34% thought that heat pumps were too expensive to run. These findings are also reflected in a study published by DECC (2013b). Although the survey by Caird et al. (2012) found that most users were satisfied with the reliability, heating, hot water, and comfort provided by their system, significant differences were observed in efficiency between owner-occupied dwellings and social housing. Owner-occupiers' greater satisfaction with space heating (79% satisfied) and comfort (91% satisfied) compared to social housing residents (67% and 71% satisfied), is attributed to interaction between differences in the systems, dwellings and users at the private and social housing sites. Higher system efficiencies were associated with greater user understanding of their heat pump system, and how users operate the system.

Concerns remain about whether ASWHPs potential can be realised, especially in the extent to which inefficient installation and use of heat pumps can reduce performance (EST, 2010; Fawcett, 2011). Empirical investigation shows that performance of domestic heat pumps varies considerably across installations, with ASHPs rarely achieving maximal design efficiency. The UK's largest independent field trial on heat pump technology, which monitored 83 heat pumps in residential properties for 12 months, found the coefficient of performance (COP)[1] ranged between 1.2 and 3.3. The average system efficiency of GSHP was 2.39, and the average for ASWHP was 1.82, lower than in other European studies (for example, Christensen et al., 2011), with most of the installed systems

not reaching the estimated benchmark for 'renewable energy' (Staffell et al., 2015: 116). This study demonstrates the complex range of interacting variables affecting performance, including UK weather conditions, installation and commissioning practices, and customer behaviour. Many householders had difficulty understanding their heat pump operating instructions (EST, 2010). Previous studies indicate that potential energy efficiency gains may be compromised by householders' use of heat pumps: a study of Danish dwellings, (Gram-Hanssen et al., 2012) concludes that expected reductions in electricity consumption are only partially achieved in real life settings. Similar findings were reported in a recent study of 28 Norwegian households (Wither & Wilhite, 2014), confirming the findings of the UK EST trials–that energy efficiency gains may be compromised not only by the design and installation of heat pumps, but by their use.

Linking Provision and Practice

A *systems of provision* perspective recognises the relationship between providers of energy services, the consumers of those services, and infrastructures (Chappells et al., 2000); and comprises the assemblage of institutions, agencies, material elements, mechanisms, and practices that might enable the transformation of energy systems to reduce CO_2 emissions.

We suggest that examination of the current discrepancy between uptake and government targets for the expansion of domestic heat pumps in the UK moves away from conceptualising the fate of innovations as lying in the hands of an individual consumer and engages with the ways production and consumption of energy co-evolve and are mediated through the work of everyday practice. Relations between the provision of energy services and the practices through which they are enrolled are critical for understanding how a new technology such as heat pumps is embraced, sidelined or contested within the home.

Whilst the dynamics of these relations exist at multiple levels and involve multiple actors, the research reported here envisages the socio-technology of heat pumps largely through the eyes of new adopters and defines the energy services they receive as combined with everyday household practices, leading to what van Vliet (2012: 263) describes as 'a practice-inclusive perspective' of energy systems, including infrastructure networks. The relationship between wider systems and the household is conceptualised by Schatzchi (2015: 15) as 'bundles of practices and material arrangements', the latter being 'collections of people, artefacts, organisms and things that are linked by such matter as contiguity, causality and physical connections'. Electricity networks are organised around connections that physically link consumers to providers (Southerton et al., 2004). Viewed in this way, the ASWHP becomes the *intermediate* physical connection linking the electricity network and household practices of thermal comfort, cleanliness and airing.

The systems of provision perspective challenges the conventional conceptualisation of infrastructure networks as mostly represented in linear and straightforward terms, where resources are captured, generated, and supplied to meet consumer demands. Spaargaren (2011: 816) notes that although householders are 'being served' by utility companies, householders in turn can be said to 'serve' energy systems by reproducing their specific socio-technical regimes (Geels, 2004) for the provision to householders. Rather than being linked through a functional, unidirectional relationship, the providers and consumers

of services are dynamically connected in ways that co-produce the system (Shove & Walker, 2010; Southerton et al., 2004). From this perspective, the habits and expectations of households, and the technologies and objects they use interact with and mutually shape each other, along with arrangements associated with large-scale socio-technical systems (Sofoulis & Williams, 2008). In this manner, the production and consumption of services are linked through distinct 'systems of provision', which encompass different resources, providers, consumers and mediating technologies that interact and are structured through the 'connective tissue' of 'infrastructures and regulatory arrangements' (van Vliet et al., 2005: 116). The reordering of provision and re-arrangement of social practices such as is required for the adoption of heat pumps for domestic heat and hot water in the UK involves renewal, reconfiguration and contestation at a number of different levels.

The concept of domestication is regarded as useful in offering insight into how technologies are integrated into households, where integration is described as involving processes of negotiation with the technology, and as encompassing stages of adaptation and use (Aune, 2001; Juntunen, 2012). In understanding possible changes that take place in relation to the technology, Aune (2001: 8) suggests that the wider system may be as important as the use of the device. To understand the nature and extent of the domestication of ASWHPs, we consider the interrelation between current systems of provision, interventions, and integration with household practices.

Re-Ordering of Provision

In the linear model of large technical systems energy companies often enjoy monopolistic and hence hegemonic positions in the market place, leading them to adopt what Strengers (2013: 123) describes as a utilitarian position, promoting a reality where household energy requirements are solely determined and controlled by individual home appliance owners. Whereas in the heralded future of disaggregated co-provision and smart energy appliances digital savvy, home-owning householders are invited to hand over control of electricity use to distributors and suppliers under the guise of greater efficiency and time-saving convenience. Neither of these images yet reflects the average UK heat pump user, who is currently most likely a tenant in social housing (Fawcett, 2011).

Nevertheless, control and operation of a heat pump positions the user as participating in the provision of their own energy services and redefines their consumer role from 'captive consumer' associated with a previous universal mode of service in multiple ways (van Vliet et al., 2005; Walker & Cass, 2007), creating new possibilities for users not only to unwittingly collaborate in the reproduction of energy systems but to act as 'co-providers' of energy services. Consumers turned 'co-providers' are able to generate some of their own technological and institutional services (van Vliet et al., 2005: 49). In the UK, as elsewhere, the deployment and uptake of low carbon energy technologies within households are serving to create the basis for the emergence of alternative modes of consumption, generating requirements for renegotiation of new forms of interdependency between service providers, users and systems (van Vliet et al., 2005). Such renegotiations may involve users seeking to break away from their roles as 'captive' consumers, but may also involve establishing new forms of dependency on a widening range of service providers. For example, research in Harlow Park, a sustainable housing development in Liverpool, found that even simple tasks required negotiation with housing

providers, with the consequence that consumers are 'locked' into relationships of dependency (van Vliet et al., 2005: 85).

Furthermore, adjustments to new systems of provision introduced by social intermediaries such as landlords may be welcomed or resisted as an imposition. In the latter case disengagement means features of the new system of provision are rejected. In terms of domestication, people need time to understand and engage with new technologies and their ability to do so is often influenced by their experience with older, familiar appliances and systems of provision (Haddon, 2006). Faced with innovation in provision the same user might compare the new to the familiar favourably in some respects and unfavourably in others, depending on adjustments to elements and linkages within social practices like achieving thermal comfort or personal care regimes.

Heat pumps are acknowledged as not the easiest or most likely technology for invention, even though modifying heat pumps after installation has been observed elsewhere (Hyysalo et al., 2013).

Re-Arrangement of Practices

Rather than being a matter of individual behaviour, energy provision and use is shaped by the practices that constitute everyday life (Shove et al., 2012). Understanding energy using a practice theoretical approach means attending to the ways that consumption is configured in mundane activities and how everyday life is conducted, from cooking, washing, providing care, keeping warm or cool and so on. Practices are achieved through

> routinized (types) of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, "things" and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge (Reckwitz, 2002: 249).

Conceived as the interconnection of interdependent elements in possession of their own logics and dynamics, practices persist and evolve as new elements are inserted or taken up. Significantly, the emphasis within practice theories is on the importance of artefacts and technologies as essential to practices (Shove et al., 2012). However, the focus in most materially-oriented practice accounts remains on the role of discrete objects, artefacts and technologies rather than wider infrastructure arrangements (Strengers & Maller, 2012).

Understanding how the 'roll out' of domestic ASWHPs is undertaken, its effects and the focus on technologies within practice theories has two important implications. First, technologies such as ASWHP do not figure in isolation but are constitutive of systems of provision as well as practice (Spaargaren, 2011). Second, there is a need to develop understanding of what constitutes the material components of practice, away from a focus on individual objects to material arrangements in order to engage with the ways in which practices intersect with systems of provision.

Institutional actors support new systems of provision through various means (Schatzki, 2015), which in the case of ASWHPs in the UK, includes government-sponsored agencies such as The Energy Saving Trust, and a range of initiatives to encourage consumers to invest in microgeneration, including The Low Carbon Buildings Programme (LCBP); the Carbon Emissions Reduction Target (CERT); the Green Deal; and, most recently, the Renewable Heat Incentive (RHI). To overcome reported design, installation

and commissioning problems, an installers' certification scheme (MCS) was introduced for microgeneration in 2008, and specification of minimum technical competences, along with incorporation of minimum standards in the building regulations for low-carbon energy sources (DCLG, 2014).

Institutional actors inject certain expectations into the altered systems of provision that require the reconfiguration of domestic practices to follow trajectories towards particular outcomes. Inclusion of heat pumps in the UK government's Renewable Heat Incentive scheme is part of wider ambitions to reconfigure socio-technical practices and reduce GHG emissions. But this requires the adaptation of domestic practices towards 'appropriate' usage of heat pumps in ways that prevent consumers frequently using booster options or turning to supplementary heating. These elements of household practice can bring unintended consequences by increasing energy consumption and compromising the intentions of policy intervention. Heat pumps operate at optimum efficiency when their low level heat production is distributed continuously via under floor heating or radiators with surfaces greater than those commonly used with gas boilers. Switching to uninterrupted use contrasts with the 'blasts' of heat experienced when gas boilers fire up or electric storage heaters peak and fade and can be disconcerting for users and requires the establishment of new routines. Failure to adjust other elements of practice around the use of heat or hot water can result in inefficiencies in the new system of provision and loss of intended gains.

New technologies, user roles, forms of know-how, design, operation and so on serve to re-work existing forms of practice in ways that cannot always be anticipated to serve particular ends. In what follows, we explore the ways that ASWHPs generate openings for new forms of energy provision and consumption, whilst at the same time creating and closing down spaces for alternative modes of consumption based on the co-provision of services on the one hand and reconstituting interdependencies between users, providers and systems on the other. We consider how these dynamics of co-provision and interdependence are mediated through everyday practices of comfort, cleanliness and airing, demonstrating that it is in the interrelation between current systems of provision, interventions, and practice that enables understanding of the nature and extent of the domestication of ASWHPs. Before turning to these issues, we first introduce the research project from which this analysis is drawn and the methodologies that were employed.

The Customer Led Network Revolution (CLNR) Project and Methodology

The core objectives of the project include understanding current and likely future energy demand and examining the potential for fostering customer flexibility within the domestic and SME sectors. In order to address these objectives, and in line with the socio-technical approach adopted, the CLNR project is designed around a number of 'test cells' each of which entails a different combination of households, SMEs, low carbon technologies, tariffs, smart meters and/or monitoring equipment. Overall, the project involves the participation of over 12,600 energy customers, with the majority forming a control group that includes 8,900 domestic customers, all of which have smart meters from which half-hourly energy consumption data is recorded. The remaining customers are participating in various experimental trials and technology-specific 'control' studies[2]. Understanding

why some household practices may adapt to the electrical landscapes created and why others remain unchanged and how these varying responses intersect will contribute to knowledge of the co-construction of electricity systems and practices.

Methodology

This paper draws on qualitative interviews and home energy tours conducted with 18 households recruited from the 378 domestic customers involved in the ASWHP trial who agreed to participate in a home interview with researchers. Each of the households with an ASWHP has advanced monitoring that relays electricity consumption to the supplier every ten minutes but no other form of intervention. Participants with ASWHP were contacted directly by one of the research team, using information provided by the energy retailer, which had previously identified households that were willing to participate. The semi-structured interviews focused on building rapport with the participant while discussing their energy use in general terms. These conversations included information about occupancy, major electrical loads, heating regimes, washing and cooking practices, thoughts and feelings about electricity use, seasonality and other temporal factors as well as experiences of and responses to new technologies. Interviews were focused on two clusters within the regional network: social housing tenants in South Tyneside and County Durham. Social housing landlords had installed loft and wall insulation, where feasible, and retrofitted an ASWHP at no cost to the tenants. Interview participants had lived with the ASWHP for between 6–12 months, including the winter months. Interviews were conducted between January and March 2013.

In South Tyneside ASWHPs replaced electric night storage heaters, gas-ducted air and solid fuel/ back boilers, funded through the Renewable Heat Premium Payment, Carbon Emissions Reduction Target (CERT), Community Energy Saving Programme (CESP), and British Gas. Installation of the air-to-water system, which distributes heat via a wet central heating system, took place following engagement with tenants of interwar housing in a suburban location, which included individual surveys, an invitation to attend a meeting at a local community centre, and visits to a fully operational Show Home so tenants could see an unfamiliar technology installed and experience its effects in an almost identical domestic setting. The refusal rate amongst tenants was reportedly low, mainly limited to cases of ill-health. (South Tyneside Homes, 2012)

In rural County Durham, 24 ASWHP were fitted in a social housing retirement development of terraced one bedroom, single story dwellings. The properties were built between 1900–1910, and previously supplied by a communal gas boiler that provided piped hot water and heating to all the homes in the complex. As a result of these contexts, it should be noted that the participants from whom evidence is drawn, are representative of older and more vulnerable households. The majority are retired or semi-retired, living in small (1 or 2 bedroom) properties.

Interviews typically lasted 60 to 90 minutes, including home tour, and were digitally recorded. Household details, audio recordings, photographs, and drawings were collected with participants' consent, and analysed together with field notes and interviewers' reflections. A qualitative data analysis (QDA) software package, NVivo 9, was used to organise and thematically code data.

Below, we explore some of our initial findings and analysis related to the ways in which ASWHPs have come to intervene in the energy provision system, and

implications for household routines and practices.

ASWHPs in Social Housing and Provision of Energy Services

The Legacy of Existing Systems

Adoption and use may be influenced by initial contacts between users and the technology, as suggested by Owen et al., (2012), however, discussions with our participants revealed the importance of the legacy of existing heating systems in shaping the ways people related to the introduction of the ASWHP, an aspect acknowledged as significant by Owen et al. (2012) and Juntunen (2014). Participants with a communal system of heating and hot water reported that it was *'tip top'* (Male tenant, DC031) and they *'never had no problems'* (Male tenant, DC035). In contrast, participants who had lived with electric storage heating systems, regarded ASWHPs as a considerable improvement to dependence on various expensive forms of electrically produced heat:

> 'You had no heat. They [storage heaters] were supposed to stay warm all day but they were cold by 11 o'clock so you were freezing. I had to use the electric fire all the time… but now I hardly ever use it… Well, I was putting £35 to 40 a week on with the storage radiators but now I'm putting £20 on now. I couldn't have afforded the other. It was terrible'. *(Female tenant, ST004)*

> 'You had no control over them […] when I come in [from work] in the evening, the place was cold. They only have bricks with a heating element, so once they switch off at 7 o'clock [in the morning] they start cooling down, so by the time I'm getting here in at 7–8 o'clock [in the evening] or whatever, the place was cold and I can't do anything. I can't turn the heating on cause they won't switch on again until midnight, and I've got no control.' *(Male tenant, ST011)*

Among those who had managed to control their night-storage heating system, the ASWHP was initially resisted, but where participants had felt unable to achieve the kinds of thermal comfort they required the possibility of improvement was greatly welcomed; not least because it seemed to offer a new means to control their energy services either by reducing dependence on and cost of portable electrical heaters or because of the perceived challenge of controlling the pre-existing system. Optimising the performance of the ASWHP requires users to adopt different patterns of energy use based on its continual, low-level provision (Cantor, 2011). Users' expectations and practices are critical in shaping how the system is operated. For some, existing daily routines over-rode the system imperatives, and users played an active role in reshaping the technology to their needs:

> 'When I'm working shifts what I normally do when I go out first thing in the morning I'll switch it off completely. […] so then put it on auto for 5 o'clock, or if it gets too cold, like the last few weeks, I'll just come in and put it on.' *(Male tenant, ST011)*

For others, the ASWHP necessitated a new mode of operation and patterns of use surrounding domestic space heating and hot water. Householders with electric night storage were familiar with the Economy 7 tariff and this enabled understanding that the ASWHP heated water during the early hours of the morning. However, some were advised they could not continue the

cheaper nighttime tariff for the AHSP, which led to confusion.

> 'We try not to have the water and the heating on together because it pulls too much, so the water comes on on a morning then it goes off for a little while. It's not that it's expensive, it's just my husband being careful. If you've got heating and hot water on the water doesn't heat up as much [...] so we just don't put the heating on.' *(Couple, ST010)*

For many, the demands of active participation in the provision of energy services seemed too great. Some had tried and failed to ensure that the ASWHP provided the energy services they required. Several had concerns about whether running the system all day–technically the most efficient usage–would incur additional costs (see also Owen et al., 2012). Others sought to distance themselves from the technology, fearing their actions may lead to the breakdown of the system and loss of heating and hot water.

> 'That's the control which I do NOT touch. I operate it from the thermostat.' *(Female tenant, ST005)*

> 'I don't let anybody touch anything. I don't want to know. As long as it's working, I don't want to know.' *(Female tenant, ST009)*

In these cases, co-provision of energy services is not celebrated, but resisted, ignored or feared. This may reflect the social and demographic make-up of the sample of participants, and their position as tenants in social housing over which they may traditionally have held little sway. At the same time, they also reflect the process of installation and instruction that participants experienced, as suggested by

Figure 1(a). Hot water boost (top) and main control with handwritten instruction to leave in set positions (below)

Figure 1(b). Thermostat control

Owen et al. (2012). Many participants found the system operating instructions difficult to grasp and the controls made little sense. Recounting the advice received from the social housing provider on re-setting the system, householders remained confused:

> 'If it goes off and needs reset... Switch it off from the inside, then switch it off from the outside. Give it a couple of minutes then switch it back on from the outside first, then come in and switch it on from the inside. And that should re-set it. [...] The people I am asking information off I don't think they are fully aware with it being a new system and that. [...] I'm not sure whether they know that much about it.' *(Male tenant, ST011)*

Despite that, at the time of interview, most householders reached a point where they were able to operate the system at a basic level using the up and down arrows on the thermostat (Figure 1[b]), but they stuck to the programme set initially on installation:

> 'They just put it in and I've left it as it was [...] I wouldn't know what to do. That's the only trouble. They didn't really tell you much about anything.' *(Female tenant, ST004)*

A few more technically literate had changed the programme settings to suit their own preferences or understandings, however, even the more competent had some difficulty with the technical information supplied, as illustrated by the comments from a recently retired electrical engineer:

> 'I wasn't happy with the times they had set. So I tried to set the timer myself. So eventually I got there. Reading the book over and over and over again.' *(Male tenant, ST008)*

Others found they had poor grasp of how the system operated and what to do, particularly outside of normal operating conditions:

> 'The red light starts flashing and I just do not know why. And I think, 'Oh God there's something wrong.' Nobody told me that the light would go flashing red, you know. When you don't know, naturally I am the age that I worry.' *(Female tenant, ST009)*

These responses echo the findings of the wider UK EST trial by judging the operations and controls of their ASWHP systems as 'baffling'; a fact that is notable in comparison to a Danish study where references to the intricacies of using the technology do not feature, despite respondents being 'in general older and less affluent than the rest of the population' (Gram-Hanssen et al., 2012: 265). This suggests that how installation and instruction are undertaken is critical in shaping the initial reception of ASWHPs and the extent to which users become willing participants (Owen et al., 2012). It also echoes the finding that the scope for autonomy, which in turn appears to shape the extent to which users are able to reconsider their roles as passive consumers and engage in forms of co-provision, is shaped by the degree providers are willing to delegate responsibilities or instead import their own notions of 'sustainable living' through interventions (van Vliet et al., 2005). Through these means, the deployment of ASWHPs appears caught in an uneasy tension between new patterns of energy use and modes of operation required from users on the one hand and the continued focus on consumers as passive recipients of energy services on the other.

Creation of New Interdependencies

The negotiation over what it entails to be an operator and user of ASWHPs, between household members, users and providers, and various agents also requires a reworking of interdependencies across the system of energy service provision. Such forms of negotiation and interdependence were visible when the ASWHP failed or required some form of technical intervention. Users, puzzled by the control and operation of the system, turn to a range of trusted providers for support but often found they too had limited understanding of the system and effective solutions:

> 'Got the plumber in and the plumber looked and says, "I don't know anything about this system" and he's gone. Why didn't they train these people? [...] I'm still worried about that [leak from the tank].' *(Male tenant, ST010)*

> 'He [housing maintenance officer] was here about an hour and a half. They hadn't been trained. He didn't know what to do. He felt awful. I got all the brochures out, he looked through them and studied them, he went out the back. He didn't know what [...] so he got onto his boss. [...] Then [the installer] come out on the Monday [...] so I'd had no hot water and heating since Friday. The [IT engineer] had turned the electric off and hadn't put it back on... I was having to boil a kettle to have a wash [...] It was like the 1920s.' *(Female tenant, ST006)*

While households could marshal different coping mechanisms, several reported that the breakdown of the system, both technically and in terms of the usual means through which energy services were provided, repaired and restored, led to significant disruption:

> 'A lot of people still do not understand the heat system... I was without heat for a week. I don't know. It just went off. It just didn't work. And I was freezing, absolutely freezing.' *(Female tenant, ST005)*

> 'I had three air source heat pumps put in. The first two were no good. I was without heating for a month... They were broken when they were first put it. [...] It was February/March, so it was pretty cold.' *(Female tenant, ST004)*

Users of ASWHPs became dependent on a new constellation of providers. Social landlords and utility companies were reliant on manufactures and specialist repair services that were misaligned in the management and repair of this particular technological innovation. At the same time, providers and installers regarded users as critical to effective operation of the system to deliver energy services. Users were also dependent on others to determine the success or otherwise of the technology. Having lived with the ASWHP for several months, many householders remained uncertain about the performance of the ASWHP:

> '[We] still really don't know if we're saving anything. We've got this wireless system in that sends information to [electricity retailer] but we haven't had any reports back or anything like that.' *(Male tenant, ST010)*

The interview data indicates that householders do not 'actively' manage electricity consumption or read their electricity meter regularly, but continue to rely on their electricity provider to provide this information through periodic, usually quarterly, billing. For most householders interviewed, consumption is evaluated

based on cost, not kWh used. Energy pricing is not straightforward, with some energy suppliers exacting a standing charge (a fixed daily charge), along with different unit rates for peak and off-peak electricity depending on the tariff, so difficult to calculate. Even where householders monitor electricity consumption, most do not understand how the system works, and are unlikely to know how to optimise their ASWHP for most efficient operation (Boait et al., 2011; Caird et al., 2012).

Far from being a straightforward installation of a technological device, this analysis demonstrates how the intervention of ASWHPs in existing systems of provision entails the reworking of the roles of providers, users and intermediaries from relatively stable positions to a more differentiated system where roles are multiple and dynamic, subject to contestation and resistance. The processes of installation, instruction, repair and feedback provide some of the sites in which this negotiation occurs, whereby new forms of interdependency are realised and negotiated, providing one explanation as to why other studies (e.g. Owen et al., 2012) have found that the initial encounters with ASWHPs are critical to their 'social lives' in households (Bauman, 2013). The ways that systems of provision are (re)aligned, enable role differentiation, and create space for co-provision appears critical for understanding how and why ASWHPs are and are not able to realise their potential. These processes are conditioned through the ways heating and hot water are used within household practices, which in turn serve to provide the means through which ASWHPs become domesticated, taken up or left out of the provision and use of energy.

Domesticating AWSHP: The Re-Arrangement of Existing Routines and Practices

Pantzar (1997: 65) argues technological systems exist only 'in and through' their reproduction in micro-social interactions, inferring that the household is a fruitful location for understanding processes of technological domestication. Reflecting on the concept and 'process' of domestication outlined earlier, and drawing on interviews with users, we consider the extent to which ASWHPs are integrated within practices of comfort, cleanliness, drying laundry and so on.

Here we consider how householders might adapt familiar patterns of interaction surrounding previous systems of provision to assemble new routines associated with ASWHP. As indicated in Table 1, ASWHP creates a strikingly different resource for practices relating to thermal comfort, when compared with other forms of heating. UK householders in our study who converted from gas-fired central heating tended to conceptualise the newly installed ASWHP as a boiler, anticipating a similarly rapid response only to find discrepancies between cooler running radiator temperatures produced by an ASWHP and higher running temperatures of boiler fired radiators (cf. Owens et al., 2012). Comparison with the old system of provision can lead to resistance to the new, which may be perceived as failing to meet established standards of performance.

> 'The radiators never get hot... When I first set the timer. I'm getting up half past six and they're freezing cold. It takes an hour for the pump to run to get them warmed up.' *(Male tenant, ST008)*

In the UK these notions of thermal comfort–rapid response and high running temperatures–are linked to expectations

of uninterruptable supplies of hot water in order to meet what have become incontrovertible conventions of cleanliness for bodies, clothes and homes (Chappells & Shove, 2004). In recent decades, the development and dissemination of gas or oil fired hot water central heating systems facilitated on-tap hot water for bathing, laundering or washing dishes. The affordances offered by this co-evolution of hot water and heating services fostered assumptions that cleanliness regimes are ideally carried out in thermally 'comfortable' homes: creating a perfect circle of energy consumption associated with relatively cheap and plentiful North Sea gas (Brinkley & Mcllveen, 2010). ASWHPs challenge these widespread assumptions and related practices by prompting novel meanings and actions that may be adopted with more or less certainty. Some changes to practices were observed: for example in our study where dwellings previously had electric night storage heating, the main change noted after installation of ASWHP occurred around using supplementary heating. Some people gladly abandoned supplementary heat sources. However, householders retained an electric heater with a flame effect for the cosy 'glow', and because it acted as a 'focal point'–valued features that the ASWHP could not provide. It also served as back-up in case of technical failure. Others adopted caution towards sole dependence on ASWHP and even considered reverting to supplementary heating.

Figure 2. Air source to water heat pump external unit, South Tyneside, showing new elements being fitted into the existing physical external space. This example indicates how integration between the old and the new extends beyond the immediate energy related practices such as heating, washing and ventilation, to other activities such as gardening.

Strathern (1994: vii) defines domestication as 'the manner in which people convert things to ends of their own'. Viewed like this the newly installed ASWHP can be understood as a focus for negotiating new and unfamiliar practices within the everyday dynamics of household relations. These processes of technological transition, however innovative, 'work on what is already there, what already gives shape to people's lives' (Strathern 1994: vi). Hence take-up of ASWHPs in the UK is bound to understandings and know-how associated with currently dominant space heating regimes, so people who move from gas boiler to ASWHP have to acclimatise to lacking instant availability of heating and to lower ambient temperatures.

> 'The radiators, they don't actually get as hot as your conventional heaters' *(Male tenant, ST007).*

Householders shifting from storage heaters (with or without supplementary heating) and electric hot water systems make adjustments that sometimes result in lowered awareness of their energy use and lead to high rates of electricity consumption.

> 'The booster is brilliant. [...] if we've let the water get too cold. It takes less than an hour' *Couple (ST010).*

There is a danger for ASWHPs to actually increase energy consumption (e.g. Winther & Wilhite, 2014) leading some researchers to conclude that depending on context, installation procedures and demographic factors, as well as variations in dwellings and the purposes they serve, a heat pump can be viewed as 'a wolf in sheep's clothing' (Christensen et al., 2011). However one potential counteraction to increased electricity consumption following installation of heat pumps in dwellings previously fitted with electric night storage heating are changes to the use of supplementary heating. Some householders discontinued supplementary heating altogether–

> 'I don't use that [electric fire] now... I used to when I had the storage heaters though' *(Male tenant, ST011).*

In this case a once desirable resource is dispensed with and another practice – that of relying on the ASWHP for thermal comfort is configured. However, this energy saving effect is not universal as others are more reluctant to depend solely on ASWHP

> 'I was thinking about getting one of those gas ones, just in case [...] I used to have a one but got rid of it. I wish I'd never have done now' *(Male tenant, DC032).* In this case an old resource and associated practice is resurrected out of apprehension about the new technology.

Learning New Practices

In some cases, householders found their potential to engage in the rearrangement of practices disrupted by existing desires, understandings and routines that were able to change only incrementally, if at all. For others, the perceived technological intricacies of the ASWHP and uncertainties about who would manage the technology and ensure that their needs were met led to feelings of resistance and alienation. In other cases, however, we found that the arrival of new technologies was welcomed and existing practices were either able to encompass the new technology and the forms of heat and hot water it provided, or rapidly reconfigured in order to do so.

Constructing a satisfactory fit between established practices and emerging ones

comes more easily to some householders and in relation to certain practices. For example, the fact that the ASWHP generates a different kind of heat to her old system led one woman to declare: '*I'm glad I've got it in now because it dries the washing beautifully'* (Female tenant, ST005). Hot water provision is considered the least problematic change. Householders judge the service provided by the ASWHP to be equivalent or better than previous systems. Overall, hot water practices remained largely unchanged mainly because the new system meets users' expectations and exerts no adaptive pressure.

There is little evidence of changes in established ventilation practices following the installation of the ASWHP. Householders with a declared long standing liking for 'fresh air' continued to leave windows open through the day, and sometimes overnight, while keeping the heating on. One householder abandoned open windows as a solution to over-heating because the lower-running temperature of the ASWHP resolved the problem.

Many tenants felt disempowered by their landlords' decision to introduce the new heating and water heating technology and did not know how to adjust household practices accordingly. Some were afraid of the ASWHP and tried to distance themselves from it while living apprehensively with the unavoidable consequences of its presence. Interviews demonstrate feelings of alienation to be more or less extreme according to age, gender, experience and single occupancy. The most alienated and troubled users in our sample are elderly women, living alone who regarded themselves as technologically ignorant, although problems are not restricted to these users.

Enabling Changes to Energy Provision through Intermediaries

As well as landlords, installers and suppliers are implicated in fostering forms of inertia that countervail the technological innovation. They fail to enact their necessary new role as effective *innovation* intermediaries (Bessant & Rush, 1995; Howells, 2006) between users and the new technology, specifically *user side* intermediaries (Stewart & Hyysalo, 2008). Users receive insufficient explanation and interpretation of the ASWHP and lack post-installation advice and oversight. Better follow up services tailored to the specific user groups could enable installers to also act as intermediaries between housing tenants and landlord. The latter are not as familiar with or well informed about ASWHP performance as installers. Whilst installers are in the best position to assist tenants to make the transition to a new technology with a user interface that appears complex to people with low levels of technical know-how, the interview data suggests they may lack the capacity–necessitating changes to the way heat pump retrofit projects are formulated and implemented.

There is scope for considering new business models for the provision of low carbon energy systems, for example one where 'servicing' a heating system was not focused on the technology (e.g. the boiler) but instead 'practice' (e.g. of comfort), giving hands on advice and passing on know-how, in a way that was regularly repeated. It might also suggest new roles for *practice* intermediaries in the domestic provision and use of energy services, such as in this case in social housing; this represents a new or extended intermediary role for landlords, focusing on enactment. A subset of user side innovation intermediaries, practice intermediaries seek to engage with users to assemble elements and linkages to configure usage of the ASWHP

and associated practices, and facilitate recruitment to new forms of practice in relation to the use of energy through, for example, peer-to-peer learning between different housing developments which have 'lived through' ASWHPs, to hands on demonstrations of how such technologies work within the context of ordinary homes and everyday routines. The importance of learning through peer-to-peer interaction is recognised by Heiskanen et al. (2014), as is online advice and peer support (Hyysalo et al., 2013b), in appropriating heat pumps. Similar arguments have been made under the concept of 'local experts' (Stewart, 2007) and user side innovation intermediaries regarding ICT use. Rather than regarding users as simply passive adopters of new technologies, such approaches would recognise the vital work that users perform in maintaining and transforming energy systems, and a basis through which to engage households in new ways of thinking about and 'doing' energy use.

The domestication of an 'all electric' system of provision involves configuring infrastructure, bureaucracies, manufac–turers, installers and service providers together with householders' routines, competencies and knowledge, acquired and transacted within their social groups and entrenched in everyday life (Elzen et al., 2004). Additionally, we must integrate an understanding of things as active 'participants' in social worlds in order to understand the impact of low carbon technologies on energy systems.

Conclusion

The preceding analysis raises several key points for understanding how novel low carbon thermal technologies become integrated into households everyday life, and implications for changing practices, and systems of provision. From installation and study of household practices for a short period after, this study makes visible various practices of integrating technology as part of everyday life, providing insight into the details of installation and use. It reveals the constellation of different actors and diverse interests required to make ASWHPs effective. This perspective is critical for the UK where housing and energy are separately organised and structured, without integrated policy contexts (e.g. of municipal ownership of both housing and energy systems when fuel is paid for through rent) that exist in other locations where heat pumps are widely adopted.

Rather than being a straightforward matter of the insertion of technologies within domestic spaces, we have argued that understanding the roll out of new low carbon technologies needs to be couched in an understanding of how such systems are co-constituted in the interrelation between the provision of energy services and user practices. A newly installed domestic heat pump stands at the interface between new and old practices and wider systems of provision, which include energy infrastructure and housing providers. While the sample included in this study may have experienced particular challenges, given their socio-demographic background and their position as tenants in social housing with implications for engagement with the technology, these findings accord with the results of other studies which have found that ASWHPs do not always perform as expected. ASWHPs are taken up within existing social relations and everyday practices, such that rather than being adopted in the manner by which designers intend, they are assimilated within the particular socio-technical contexts. Far from being a universal solution, ASWHP introduce considerable disjunction in systems of provision in the UK. Our results demonstrate that it is insufficient to 'roll

out' technologies without considering the distributed relationships involved, and the need for local configuration of multiple logics.

The challenge involved in reconfiguring systems of provision and re-ordering practices is further illustrated by the complexity of relations involved between tenants, social housing landlords, suppliers, installers and electricity providers. Emerging from the context of these changing systems of provision and new forms of sustainable practice is a need for *user-side* intermediaries–to bring together the social and the technical. The severe paucity of information and coaching in the use of ASWHP indicates a role for different forms of intermediaries: whether to provide user-side support to recruit occupants to new practices, installer training on engaging with users, and chains of support from manufacturers.

Although the number of households may be a limitation of the study, results suggest that the social response to ASWHPs is far from homogenous, varies considerably even within similar socio-demographic and housing tenure contexts, and are shaped by the legacies of the systems of provision that are removed to make way for ASWHPs and the forms of everyday practices within which these technologies and the services they provide are enrolled.

The findings of this study are particularly important in a context where significant emphasis is being placed on the potential of new domestic technologies to advance a low carbon transition. Effective strategies to encourage integration of heat pumps requires policy-makers be informed by improved understanding of how they become embedded within existing thermal systems and practices. Current models of deployment tend to assume that, provided with basic information, users will come to learn how to use new technologies efficiently. This study suggests that this is not the case. Instead the desires, understandings, routines, and other ingredients that go to make up the practices of comfort, cleanliness, drying laundry and so on within which the provision of domestic heat and hot water are located are critical in shaping the process of domestication and the extent to which new technologies can play the role envisaged by their designers.

In working towards broadening the uptake of ASWHPs, these findings point to the importance of attending to how new domestic technologies can be more productively introduced and interwoven into household practices. A better system of provision is required if ASWHPs are to be welcomed as an advancement in the provision of heating and hot water for social housing and their reputation is to be enhanced.

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Notes

1 The Coefficient of Performance (COP) is the ratio of heat output to electrical input for the technology, a measure of energy efficiency. A higher COP denotes higher efficiency. An alternative standard of performance, the Seasonal Performance Factor (SPF) is a measure of seasonal efficiency, which is defined as the useful thermal energy delivered over the year divided by the electricity input over a year, and may be a more realistic measure. This is typically lower than the COP measured at any one point in time.
2 Further details of the technologies trialled is provided on the CLNR website at http://www.networkrevolution.co.uk.

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Pilot Users and Their Families: Inventing Flexible Practices in the Smart Grid

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Households are increasingly the centre of attention in smart grid experiments, where they are dominantly framed in a role as 'flexible consumers' of electricity. This paper reports from the Danish smart grid demonstration project eFlex, which aimed to investigate the 'flexibility potential' of households, and it shows how householders are far from just 'consumers' in the system. Drawing on empirical material from ethnographic fieldwork in 49 households that tested smart grid equipment, the paper firstly demonstrates how eFlex users were also creative innovators. Secondly, by integrating user innovation literature, domestication theory and practice theory, the paper illustrates how the eFlex equipment interacted with a variety of collectively shared everyday practices in the household and argues that this unique family context accordingly had implications for the 'innovative capacity' of these pioneer users. The paper thus calls for smart grid stakeholders to begin taking the 'innovator role' of smart home users seriously, but equally calls for a more contextual and situated perspective when involving innovative users – their families have an equal part to play in the development of the smart grid.

Keywords: user innovation, family context, smart grid

Introduction

There is no end to the possibilities and benefits embedded in the vision of the smart grid. Globally, it is teeming with projects, plans, experiments and policy road maps for developing this modernisation of the energy system. According to the smart grid stakeholders, one of the important tasks for realising the smart grid is to promote 'flexibility' on the consumption side. Most smart grid projects to date have focused on developing technologies, but increasingly the 'consumer side' has been the centre of attention (Verbong et al., 2013), where the challenge is to unravel how end-users can be motivated to take on the role as flexible consumers.

The bulk of these projects have a rather individualistic and techno-economic approach and often test traditional consumer incentives through quantitative methods by, for example, surveying the response to price signals or detailed information on energy consumption (Gangale et al., 2013).

This paper reports from a smart grid user study which aimed to explore what additional motivations could be in play regarding customers' 'flexibility potential'.

The eFlex project was a user oriented innovation project that was commissioned by the largest utility company in Denmark, DONG Energy (DE). The company hired a consultancy firm to generate in-depth qualitative knowledge on the use of smart grid technology in everyday life through anthropological fieldwork in households in the Copenhagen area.

During the analysis of the empirical material from the user study, I found that many of the 'pilot users' were extensive do-it-yourself enthusiasts, who found innovative uses of the equipment they were given, which moved beyond its intended use. They also had ideas for improving the equipment and even performed concrete technical innovations to it. The households in the smart grid experiment were thus among the recent array of studies that report *energy users as active innovators* (the theme is increasingly gaining attention, see, for example, Heiskanen & Matschoss, 2012; Hielscher et al., 2013; Hyysalo et al., 2013a; Hyysalo et al., 2013b; Juntunen, 2014; Ornetzeder & Rohracher, 2006; Smith et al., 2013).

That the users' innovative capacity in relation to developing the smart grid has not been explored more is especially peculiar in a Danish context, since the government in 2006 announced it would spend DKK 420 million on promoting user driven innovation through a programme, which would last until 2014 (Elgaard Jensen, 2012). A few smart grid projects in Denmark have built on user involvement in the development of energy technologies and systems (e.g. DREAM, eFlex, MCHA), but they have not focused on actual user innovations.

This paper will focus on this particular perspective (see Nyborg & Røpke, 2013, for other aspects of the eFlex project) through the following research questions:

1. How was the eFlex equipment integrated into everyday life in households?
2. What inventive uses and adaptations did the householders make to the eFlex equipment during this integration?
3. What did the family context mean for the users' experimentation?

Although these questions depart from the questions normally posed in smart grid 'consumer studies', the answers will be interesting to system builders, as they address issues about 'the sources of innovation' (von Hippel, 1988) and underline how designers of future systems should recognise that "creativity on the fringes should be appreciated and brought in" (Elgaard Jensen, 2013: 356). Moreover, although the study focuses on innovative users, it also differs from most studies on user-innovators: By approaching the empirical material with a theoretical perspective, which has roots in science and technology studies (S&TS), I also aim to argue for a more situated, contextual and systemic perspective on user innovation than the one Eric von Hippel and colleagues represent.

Accordingly, my analysis of empirical data is informed by three theoretical perspectives: domestication theory (e.g. Berker et al., 2006; Lie & Sørensen, 1996; Silverstone & Hirsch, 1992), social practice theories (mainly as developed by Shove et al., 2007; Shove et al., 2012) and literature on lead users and user innovations (e.g. Franke et al., 2006; Lüthje, 2004; Schuhmacher & Kuester, 2012; von Hippel, 1988, 2005).

The article will be structured as follows: First the eFlex project and the user study will be introduced, followed by a description of the theoretical frame and the methods used. The empirical findings that follow

are concerned with how the equipment was domesticated and how it interacted with a variety of domestic practices; how the users experimented and made various innovations, and how these processes and the affordances of the equipment led to conflicts and negotiations in the families. Finally, the paper will discuss how context matters for innovative processes and for 'the commercial attractiveness' of an innovation.

The eFlex Project

In a Danish context, the transition to a low carbon energy system is dominantly framed as an issue of integrating more wind power and using the increasing electricity production for heating (heat pumps) and transport (electric cars) (Energinet.dk & Dansk Energi, 2010). By enabling 'flexible' consumption patterns, the smart grid is argued to resolve issues concerning an increasing share of intermittent energy sources in the system and emerging, new loads from, for example, electric cars and heat pumps.

The eFlex project was commissioned by DE Distribution and conducted throughout 2011. It involved the testing of new smart grid prototype technologies for demand management of electric vehicles, heat pumps and domestic appliances in 119 households in DE's distribution area. The consultancy firm Antropologerne was hired to perform a user study that explored the customers' price sensitivity and different motivations for being flexible consumers. As part of the data collection for my own research project, I was allowed access to the households involved in the user study and conducted 11 of the 49 household interviews included in the study.

The eFlex project design and the intended use of the smart grid equipment

A basic element in the project design was testing of a home automation energy management system, which supported a new communication interface with DE and enabled visualisation of the customers' appliance-specific consumption. The hypothesis was that it would create a new relationship with DE and with electricity as a product, which would encourage flexibility and increase customer acceptance of supply interruption – as well as providing the ability to automate the management of consumption conveniently.

I use the notion of 'intended use' to convey the designed-in features of the eFlex pilot study. This is because the design and equipment in the eFlex project could not be explored in minute detail to infer the sets of "scripts" (Akrich, 1992) they may have – as other interactive ICT's the eFlex equipment appeared to "have more complex affordances than clear scripts" (Hyysalo, 2010: 245). The eFlex system consisted of a number of intelligent power nodes, which the users could control via an on-line 'portal' that could be accessed from either a computer or from an iPod Touch. If the users connected the power nodes to appliances around the house, they would be able to see on the portal how much power each appliance consumed throughout the day. The system was designed so that they could turn them off from the portal, or they could program certain power nodes to turn off or on collectively at specific times of the day, and thus make, for example, an 'out' profile, or 'sleep' profile'. Moreover, the participants had agreed to transfer to hourly pricing and were offered variable distribution grid tariffs. Accordingly, the next 24 hours' dynamic prices, which were visible on the portal, and which the customers were priced after, were based on a combination of dynamic spot prices and variable tariffs and could differ from 1.50 kr. (0,20 €) pr. kWh to 4.30 kr. (0,58€) pr. kWh. Hence, the users were expected to utilise this information to construct certain profiles or turn devices on/off individually

at certain times in periods when the price was low/high.

The eFlex project design included 81 households with a ground source or air-water heat pump (HP), 9 households with an electric car (EC), and a 'control group' of 26 'ordinary' households (OH) without either. All three groups had the energy management system described above. In the heat pump group, DE could reduce consumption – or 'optimise' – the heat pump externally for periods of one to three hours through a 'relay box'. This externally optimized group had an extra feature on the portal they could use to follow DE's interaction with the heat pump. Likewise, the charging of the electric car batteries was controlled externally by DE. In this case, the users had to specify through the portal at what time in the morning the battery should be ready and charged, and its minimum percentage level (see Nyborg & Røpke, 2013, for a more detailed description of the design, method and results of the eFlex user study).

Theoretical Frame

The theoretical frame applied in the analysis of the empirical material builds upon domestication theory and a theory of social practices as it has been developed in relation to (energy) consumption, materiality and everyday life (e.g. Reckwitz, 2002; Shove et al., 2007; Shove et al., 2012; Warde, 2005). Whereas domestication theory is an obvious candidate when analysing what happens to both the artefact and the family when new technology enters the front door, a practice theory perspective clarifies how the technology comes in clinch with a variety of everyday practices that constitute the home.

Domestication theory originates in cultural-, media- and consumption studies and in S&TS and arose in the late 1980's as a response to 'the linear model of diffusion of innovations' (Rogers, 1962). The notion of 'domestication' refers to how a new and unfamiliar technology has to be 'housetrained' when it enters a household. The theory emphasises the context-dependent appropriation of artefacts and how their role in a family is an outcome of negotiations. Moreover, these "everyday struggles [...] may have important effects on the shaping of technologies and its 'consequences' " (Lie & Sørensen, 1996: 11). Domestication is a two-way process where artefacts are incorporated into routines and value systems of everyday life and may be ascribed new meanings and functions, but they may also assist in breaking habits or developing new routines in a family. Such dynamics accordingly make a domestication analysis "similar to studying acts of design and innovation" (Lie & Sørensen, 1996: 8).

Although domestication theory was developed in the wake of the pervasive 'practice turn' in contemporary social theory (Schatzki et al., 2001) and evidently pays attention to everyday life practices, social practice theories[1] offer a different theoretical lens than the one domestication theory presents. The subtle put important difference is that in domestication theory, focus is on practices 'with' an artefact and how artefacts *develop* in the continuous interaction with a household's unique culture and identity – its 'moral economy' (Silverstone & Hirsch, 1992). Although the household's unique culture is constituted by practices, the focus in domestication theory is not *on the practices as such*, but on the technology and its interaction with the moral economy of the household and the individuals that negotiate it.

Instead, social practice theories have social practices such as 'cooking', 'playing soccer', 'shopping' or 'googling' as the ontological units of analysis. By drawing on a practice theory perspective, the

emphasis is on how 'social practices' are more than 'user actions' with an artefact or everyday life activities broadly speaking. A practice can be seen as a cluster of activity, which can be conceived of as an entity and which is endurable and recognisable through space and time (Shove et al., 2007). To take an example, the practice of cooking dinner precedes the individual cook, who momentarily and at a specific place performs the practice by linking several *elements* such as artefacts, bodily movements, meanings and know-how – i.e. they 'use' a stove, know-how about how to chop a carrot and meanings such as caring for your children or norms about health. Individuals thus

> face practices-as-entities, as these are formed historically as a collective achievement; and through their own practices-as-performance, individuals reproduce and transform the entities over time. Individuals thus act as 'carriers' of practices (Røpke, 2009: 2491).

Different theorists include different elements to configure a practice, but Shove et al. (2012) and Strengers (2013), for instance, argue that 'materials' – technologies, products etc. – as well as resources such as energy are among the elements that actively constitute practices as they are performed. Consumption or patterns of demand is therefore the *outcome* of our engagement in meaningful social practices.

Thus, by integrating a practice theory perspective in the analysis, more attention is paid to the dynamics of the practices performed in the home, rather than focusing more exclusively on the 'technology-family dynamics' interaction. Articulated in this framework, new technology accordingly both changes some practices performed in the household (according to DE's intentions), but conversely, the eFlex technologies are also integrated in some practices and made to function in these practices. Domestication is thus the way each household finds its own unique way of integrating the equipment as an element in the performance of a range of its everyday practices, which accordingly may develop and diversify the practices (Røpke et al., 2010) or lead to the creation of entirely new ones. In this paper, the artefacts considered in the domestication processes are the portal, iPod touch, power nodes, 'information' (variable prices, tariffs etc.), PODIO, heat pump and electric car. 'Equipment' usually means the portal, iPod and power nodes.

Furthermore, social practice theory is well equipped to investigate "the complex temporal organisation of everyday life" (Shove et al., 2009: 1) and the relation between patterns of energy demand and 'inflexible' daily rhythms (Powells et al., 2014; Walker, 2014). In a practice theory perspective an individual follows a path in time and space, and each individual carries out practices that take up time and have to take place in space. This also implies coupling constraints, as Røpke (2009: 2493) argues

> As practices often involve other people, other living organisms as well as man-made and material objects, they depend on the coupling and uncoupling of the paths of all these human and non-human "partners".

Thus, coordinating practices and paths in a family is hard enough even without new demands that certain practices are dislocated in time through 'flexible consumption'.

Both domestication theory and the approach to understanding social practices

described above contest the idea that users – or practitioners – are 'passive recipients of innovations', a contestation thoroughly fundamental to the S&TS field (Oudshoorn & Pinch, 2003). Instead the theories emphasize that these actors are active, creative and skillful and some of the domestication literature points to how users not only ascribe new meanings and uses to artefacts to make them fit to an everyday life context, but even make concrete user modifications and 'micro-innovations' (e.g. Aune, 1996; Håpnes, 1996; Juntunen, 2014). Also, in the theory of social practices as developed in e.g. Shove et al. (2007), the individual is seen as a competent practitioner, who uses (or consumes) artefacts to engage in meaningful practices or projects such as DIY (do-it-yourself) and who simultaneously develops new skills and knowledge doing that, which has a bearing on future patterns of consumption and product development.

Shove et al. (2007) also draw on the literature on 'craft consumers' (Campbell, 2005). According to Campbell (2005: 27), craft consumers bring "skill, knowledge, judgement, love and passion to their consuming", similarly to how craftsmen approach their work. The notion 'craft consumption' is used to "refer to activities in which individuals both design and make the products that they themselves consume" (Campbell, 2005: 27). Importantly, the 'products' or creations that craft consumer make often consist of a range of items that are themselves mass-produced commodities – they use these as 'raw materials' for a new, 'personalized' creation that allows for creativity and self-expression (Campbell, 2005: 28). Areas of consumer activity in which craft dimensions most clearly exists are such as "the world of DIY and home modification and improvement, together with gardening, cooking and the building and maintaining of a wardrobe and clothing outfits" (Campbell, 2005: 33). The literature on 'creative consumers' (e.g. Berthon et al., 2007) similarly address the ability of users to "adapt, modify, or transform a proprietary offering" (Berthon et al., 2007: 39). Like the other theoretical perspectives, this literature rejects the image of users as passive 'dupes' that are subjects to market forces (Campbell, 2005) and argue that much interesting creative and innovative 'work' happens beyond the moments of acquisition[2].

However, a body of literature concerned with innovative users that has gained most attention within management research (Berthon et al., 2007), deals with the concept of the 'lead user', which was coined by von Hippel in 1986, and this paper draw inspiration from this literature. von Hippel (2011) argues that consumers are a major source of product innovations and that this innovation is highly concentrated on few 'lead users' (von Hippel, 1986). However, von Hippel pays little attention to how the meaning and use of artefacts are dependent on the context they are situated in, which thus matters for what user innovations are possible or make sense. The study of social practices and domestication processes in relation to such active users is interesting, because it can further our understanding of the users that innovate and the innovative processes they are engaged in.

According to von Hippel (1986: 796), lead users are different from 'ordinary users' and can be identified by two overall characteristics: 1) they face needs that will later become general in a market place, and 2) they are positioned to benefit by obtaining a solution to those needs. Together, these features mean that lead users are not only more likely to innovate than 'ordinary users', but also likely to develop commercially attractive innovations (Franke et al., 2006).

The first characteristic says something about a users' *capability* for making

commercially attractive innovations, because the lead users are at the leading edge of important trends; they often operate in use contexts that lie in the future for most users, i.e. they "develop a novel use for an existing commodity" (Lüthje & Herstatt, 2004: 557). Lead users are 'expert users' – they often have a lot of use experience in a product field as well as technical skills and product related knowledge and are also often freely drawing on help from a use-community (Franke & Shah, 2003; Franke et al., 2006).

The second characteristic, i.e. 'high expected benefit', relates to '*innovation likelihood'* and a users' *motivation* to innovate and seeks to explain why in some product categories it is the user and not a manufacturer that develop a certain innovation. This characteristic is among other things related to the heterogeneity of user needs: many users are dissatisfied with the existing products that are on the market, and some users will attempt to improve or develop products themselves – they benefit from *using* this solution to their specific needs (Lüthje & Herstatt, 2004). Moreover, users have 'low innovation costs' compared to manufactures in some product areas in terms of access to 'sticky information' about user needs: 'Sticky' information can be explained as the tacit knowledge the user has gained through using the product. While the user is in possession of this information for 'free', it is costly for the manufacturer to get (Lüthje & Herstatt, 2004).

Other motivational factors that characterise lead users is the enjoyment and learning that many of them experience and value from the *process* of innovating as well as recognition from peers in the user community. Some also innovate because they expect a profit from selling the innovation and not just to benefit from using it themselves (See e.g. Raasch & von Hippel, 2013).

Methodology: Empirical Material and Analytical Approach

The empirical material used in this paper consists of field notes, photos and videos from the 49 household visits, as well as dictaphone recordings from my own 11 visits. Each household visit lasted approximately 4–5 hours and included interviews with the families, as well as a 'grand tour' of the dwelling, and the field worker would also have lunch or dinner with the family. The interview guide was developed together with the researchers that took part in the project.

Table 1. Fieldwork was divided into three 'loops' – loop 1 focused mostly on the eFlex portal etc., loop 2 on electric cars and loop 3 on heat pumps. See appendix 1 for an extended table summarizing information about the author's 11 interviews.

	Loop 1, spring 2011	**Loop 2, autumn 2011**	**Loop 3, winter 2011-12**
Households included in the trial (in total 119)	29 ordinary households 26 heat pump owners	9 electric vehicle owners	55 heat pump owners
Households involved in the user study (in total 49)	16 ordinary households 6 heat pump owners	9 electric vehicle owners 3 heat pump owners	15 heat pump owners
Household interviews performed by the author (in total 11 out of 49)	1 ordinary household 2 heat pump owners	3 electric vehicle owners 1 heat pump owner	4 heat pump owners

After each household visit elaborate field notes were written on PODIO, a social media platform that functioned both as a project management tool for DE and Antropologerne and as a platform for the householders to communicate with each other and the eFlex project team.

The analytical process resembled the 'immersion/crystallization' style (Borkan, 1999) by relying on intuition and prolonged 'immersion' in the data. The analysis began by listening through all the dictaphone recordings – often 1–3 hours from each household – and writing down immediate ideas and notes for emerging themes. Subsequently, I transcribed verbatim 5 of the 11 dictaphone recordings as these focused particularly on heat pumps and were to be shared with other researchers for another paper. Concomitantly with this process, all 49 household field diaries were read through several times and emerging themes were further developed and the family stories were written. The dictaphone recordings that had not been transcribed were listened through again and relevant parts in these were also transcribed. Video recordings and photos were mostly used as 'back-up' for field diaries and dictaphone recordings; In a few cases it was for example unclear what was meant in a field diary written by another fieldworker or what was being said on my own recordings and looking through relevant photos or video-material could clarify these issues.

Evidently, this qualitative approach differs from the methods that would normally be used in conventional lead user studies. In these studies much emphasis would be put on evaluating whether the involved users are in fact lead users, i.e. do they display lead user characteristics. This is often done through surveying a user community and self-evaluations or through external domain expert evaluators (see e.g. Franke et al., 2006; Hyysalo et al., 2015). The households included in this paper are thus not 'verified lead users'. However, several of them had developed novel uses with a technology, had modified their equipment, had a lot of use experience, technical skills, were dissatisfied with the current product offers, had community based resources (e.g. PODIO, but several were also involved in heat pump and electric vehicle user communities beyond the eFlex project) and expected a benefit from using their own innovations. They also seemed to enjoy the innovation process and the learning it brought them.

Family Stories

The findings presented in the following consists firstly of two detailed family stories and secondly, I draw on these two stories supplied with empirical material from the rest of the household visits to elaborate more specifically on cross-cutting themes in the material that are related to my research questions.

The family stories are included to exemplify and give a sense of how the eFlex project became situated in different and unique family contexts; because they are *family* stories they illustrate how the inventive users were enmeshed in a household's moral economy and the web of interconnected practices that comprise it, which mattered greatly for the innovative processes and their outcome. Moreover, the stories exemplify three themes, which I, as said, will explicate more on afterwards: The story of Peter & Charlotte is a story about *domestication*, whereas the story about Benny & his wife Marie illustrates dynamics concerning *innovative processes in a domestic setting*. Both stories also illustrate the *negotiations and conflicts* that follow in the wake of introducing such equipment in a (innovative) household.

Family story of Peter & Charlotte

Peter and Charlotte love living in their large country house close to the forest and with a panoramic view over the 2.5 hectares of land they own. As Peter says, 'I am a man of nature'. The house resides in a 'well-to-do' part of northern Zealand, and the married couple share the house with their two teenage sons, who in Peter's view spend far too much time playing on the computer.

The eFlex participation is mainly Peter's project. Although less enthusiastic, Charlotte is curious about what it actually is in their household that consumes most electricity. 'Is it turning on the clock radio, the oven or the lights outside?' she asks. However, she finds it difficult to become part of the project, and she and the two boys have gotten annoyed with how Peter is running around with the iPod all the time. Peter is still experimenting with where to put the power nodes and so far none have been placed in the dining room as Charlotte finds them too ugly and not fitting in with the interior decoration. Peter has put power nodes on the TV in their bedroom, on their B&O clock radio, in the guest room for Charlotte's laptop, on their video surveillance cameras outside, on the TV, lamp and computer in each of the boys' rooms, on their routers and on the quooker and washing machine in the kitchen. The quooker is a tap in the kitchen, from which you can pour boiling water directly into your cup. The couple has realised that the quooker uses a lot of electricity because it is always on 'stand-by' – actually it uses around 1400 Watt for a few minutes several times a day, Peter can see on the portal. So now he has made a profile that turns it off at night when they never use it. He can see that the biggest consumers in the home are the boys' rooms and the kitchen.

Peter goes to bed around 12 at night – unless he stays up a bit to do some programming to improve the webshop of his store. He has set up the system so that the TV in their bedroom is the 'master', i.e. when he goes to sleep he turns off the TV, and all the rest of the things in the house connected to power nodes are also automatically turned off. Peter thinks the system functions very well, although he must admit it requires some skills to learn how to use it and its logics. One morning they were all late, because the clock radio did not turn on because it was set on a wrong profile – and Charlotte could not get her cup of tea because the quooker had not been on when they woke up.

Peter's system of turning off all devices through his iPod when he goes to sleep also means that he turns off the boys' light, TV and computer. Otherwise they will continue playing all night, get up late and be too tired in school. "So I also use it a little to control behaviour now that I have the possibility, right?" as he says. "I'm trying to raise them to know that a good night's sleep is important". He also thinks they shouldn't disturb their friends after bedtime. Actually he did signal this to them even before he had the eFlex system by shutting down their IP addresses on the internet. However, Peter recognises that often the boys would instead just use the neighbours' open WiFi, so it's more for the signalling effect, he says.

The couple realised that the boys' ICT habits actually count for a great part of the household electricity consumption. After they started staying in their rooms at night playing computers, watching TV or communicating with friends, their electricity bill rose by 3-4,000 kr. (400–530 €) a year and now the eFlex project has really confirmed that it is connected to their 'staying-in-the-room-at-night' habits, Charlotte says. Peter estimates he only saves around 500 kr. (70 €) a year turning off things at night, but he likes the idea that all unnecessary standby consumption is turned off. Peter also likes using the iPod and portal as a way of getting

a feeling of what is going on at home when he is at work:

> I think it's fun to open it [the portal] from the store and see if it's all running… and see if the boys have come home […]. Then I can see if the computers are on.

Actually, the eFlex equipment has somewhat become part of Peter's incidental 'surveillance' of the boys and their dog-walking chores. The adults take turns walking the family's dog in the morning, as do the boys when they come home from school – the agreement is to take him for half an hour in the woods. However, after the family got the surveillance video camera outside, Peter and Charlotte accidentally noticed when looking through the pictures how the boys 'cheated' and just opened the door to let him out for 5 minutes. And now, even while at work, Peter can also 'survey' whether they are actually in their rooms and playing on the computer instead of walking the dog. He can see

> what time he turns on the computer, right? I can see if there is no electricity consumption. I can look back on the entire past week and see when they've been on and when they've not been on. They don't know quite how much it's actually possible to see on it, you know?

Peter has had discussions with Charlotte about how they can be flexible, and he wants the washing machine and dishwasher to run at night, but Charlotte thinks that the clothes get wrinkly from lying in the machine all night. Furthermore, although she wants to 'learn how to save energy' and 'do things smarter', as she says, things get too much of a hassle and an inconvenience if the machines can only run at night: "If I'm suddenly cooking and I have a lot of pots and pans, then surely the machine just needs to run, so I can also use them later in the evening. Nor can I just plan to always wash clothes at night, because I do not have the time to hang them up".

Family story of Benny and Marie

Benny and Marie are a couple in their sixties who have both retired early. Benny, however, still works 10–15 hours a month as an IT consultant for his old workplace where he was employed as a mechanical engineer. They have lived in the same detached house in the suburb for almost 40 years.

Benny and Marie have had a ground source heat pump with a 300 L buffer tank for three months, because Benny wanted to take advantage of the cheap electricity their electricity company 'Modstrøm' offered them at night by storing extra heat in the tank. But then Benny found out about the eFlex project through a newsletter, which also offered cheaper prices at certain times of the day. They had been Modstrøm customers since 2008 and only recently changed to DONG Energy, because they had to as part of the eFlex project. Marie adds that they were accordingly already 'tuned in' to time-shifting their dishwasher and washing machine to night-time. Benny is very preoccupied with the heat pump and is very willing and proud to show how he can follow its 'workings' on the eFlex portal. He has even volunteered for another project called 'control your heat pump' and explains

> you get more measuring equipment on your heat pump […] you get to see even more how well it works, you can measure your COP value and so on…

Benny considers DE's optimisations of the heat pump too weak, among other things because he has the buffer tank. Consequently he shuts off the heat pump completely between 8–12 and 17–19, where

the tariffs are the most expensive. However, he has found a way to 'cheat' the heat pump in order to get heat in the radiators anyway during these expensive hours: Between 5 and 7 in the morning where electricity conversely is cheap he sets the heat pump to deliver a living room temperature of 27 degrees so the pump heats up water to meet that temperature. However, his thermostats on the radiators in the living room are not 'fully open', as many heat pump owners are told they should be, but are instead put on, for example, 21 degrees – this means the extra hot water is saved in the buffer tank instead and can be used in the expensive hours between 8 and 12.

The couple do not have a fireplace, which many other eFlex participants say they light up if they think DE's optimisations lower the household temperature, but their walls can also store a lot of heat, he thinks. Marie tells me she never turns up the thermostats as she doesn't believe it matters. But she is happy the heat pump can be set to a 'travel mode' during the winter, so the temperature does not go below 10 degrees and "the living room plants do not suffer any hardship". Marie is not always satisfied with Benny's experimentation with the heating. She doesn't know, for example, how to turn up the heat in her hobby room on the 1st floor. She tries to turn up the thermostat and says:

> but I really don't quite know what is going on in this house. But, I try to turn it up... Benny, he tries so many things, so what's going on all the time, I'm not quite aware of.

Neither is she totally happy about the temperature of the water after they have got the heat pump:

> It's got better, because it's been set a little low, but I still think it's bad with the water for dishwashing, because it has to run for so long for it to become warm enough for grease and so on to come off, and I don't think he has quite finished regulating that yet.

Benny emphasises that he *has* finished regulating it and that the temperature can't get higher than 50 degrees, unless the HP needs to use too much electricity. He has, however, set the HP to heat up the water in the system above 60 degrees about once a month to avoid legionella bacteria contamination of the water. He doesn't believe the optimisations have any influence since they never eat before 19 or shower between 8 and 12 or from 17 to 19. But Marie says

> there are things such as when I for example bake a cake and cookie dough and so on. I use water in the kitchen at many times during the day [...] it's not quite warm enough.

Benny has experimented a great deal with putting power nodes on the refrigerator, freezer (the nodes are locked so it's not possible to accidently turn them off) and dishwasher, and he is happy he can now see how much electricity they consume. He tried to put a node on the washing machine and dehumidifier in the basement but it kept shutting down. He also has a node on the circulation pump for the HP, which he at first made a turn-off profile for during the night, but now he lets it run because the price is low at night anyway, so they may as well have that comfort. Moreover, he put a node on an outside lamp, on their music system, DVD, TV, laptop, and the radio in the living room. He noticed that their hard disk recorder uses a lot of electricity, but he couldn't turn it off to save stand-by

because it's an old model that forgets all the time settings when it's turned off. Marie's frustrations not only concern the heat pump but also the eFlex equipment, because she does not really understand what the iPod or power nodes are for. Benny already has two iPods on which he recently downloaded the eFlex app and all their music, so they can bring them on car vacations, for example. He secured the iPod from DE onto a little loudspeaker system in the basement besides Marie's laptop, computer screen and printer so she can turn her ICT devices on, but she's not happy about it:

> It's really hard, because at the same time all our music is set on completely different methods… You know, Benny loves these kinds of things… 'Then you just have to push there and there' you know… And then constantly new and new and new things come along and I'm just not that much into machines… There are too many thingies and gizmos, and they are not just DONG Energy's.

Findings

Domestication and de-configurations

As we can observe in the family stories, the use of the eFlex equipment and the meanings ascribed to it are quite different between the two families. The equipment became domesticated into a family setting with its own unique moral economy, which was under constant negotiation, and which had an influence on what the equipment was actually used for and what practices it co-developed with. Taking Peter's story as an example of a domestication process, we saw how the equipment supported his and Charlotte's interests in identifying the devices consuming most in the household, quite in line with a household moral of avoiding unnecessary waste. Moreover, it inspired reflections on washing clothes and kitchenware at night, which was in line with the intended use of the equipment. However, the project and the eFlex equipment also *became something else* through the domestication process – e.g. a means for Peter to control his sons. The project entered a household with a moral economy connected to ideas and meanings about 'an active lifestyle' and a love for nature. Moreover, Peter considered it valuable for his boys to get enough sleep to perform as well as possible in school. Peter's use of the eFlex equipment was clearly domesticated into this setting, since he used the eFlex equipment in his already existing practice of controlling and surveying the sons through the video camera or the shutting down of IP addresses to signal 'bedtime'. Now, with the eFlex equipment, he instead simply shut down the computers or looked on his iPod from work when they had been in their rooms and what they were doing there. This domesticated use of the eFlex technologies was both for 'getting a feel of home', but also to explore and confront the boys' 'passive' computer games – especially at night – or their cheating with walking the dog in the forest, which was part of the nature he would like them to appreciate more.

Intended and unintended uses

Generally, domestication of the equipment led to both intended and non-intended uses. Concerning the former, knowledge about electricity prices and tariffs on the eFlex portal often inspired the moving of laundry and dishwashing – or even things such as baking and pottery hobbies – to night-time or weekends. The power nodes were often connected to lamps, TV/music-sets as well as computers and were used for identifying 'large consumers' or gaining a better sense of the consumption patterns of the household, which meant for example that they could turn off unnecessary consumption or even replace inexpedient

devices. Some users also experimented with using power nodes for 'flexibility', which actually required a rather creative use of the equipment[3]. For example, the pilot user Hans would make a profile to turn his chest freezer off from 10 pm and until 2 am. In the meantime the temperature had risen about 1 °C, so when turned on again, the freezer would restore the temperature and 'move' some of its consumption to the cheapest period after 2 am. However, as Peter's story illustrated, the equipment was also used in ways that were not according to the intended use. Another example was Martin, a dedicated father and husband, who used the iPod or computer to turn off his 3-year-old daughter's cartoons from the kitchen.

> Then, when it's time for bed, she can see we don't have the remote, because she has it, but then we can say…'Now there is no more TV [aired] today'

– an explanation she would instantly accept. In other cases, if Martin was at work and worried because he couldn't get in contact with his wife through the phone, he could see on the portal she was home, because the TV was on – and he would turn the TV on and off to see if she was awake and 'provoked' to ring him back.

Thus, the eFlex project interacted with a myriad of practices as varied as cooking, laundry, dinner and dishwashing, airing-out, watching TV, playing computer, communicating with friends, brewing tea and coffee, commuting to work, lighting a fire in the fireplace, bed-time rituals, 'leisure/passing time' practices, parenting, walking the dog, theft protection, heat comfort, hobbies and many more. New practices were, however, also created, more in line with the equipment's pre-configuration, e.g. several pilot users took up the novel practice of routinely checking the portal at night before going to bed. Although difficult to state when the equipment was integrated as a new element in an already established practice – e.g. turning on the computer and checking emails before bed – or whether the practice could be 'classified' as new, it is evident that something happened to *both* the equipment and to the practices performed in the households.

Next, I want to focus more on two specific issues that appeared in the domestication process: user innovations and conflicts and negotiations in the family.

Inventive and creative users

In the above-examined families, we saw how Eddie, for instance, developed a novel use in relation to the optimisation of his heat pump, whereas Peter was often spending time programming to improve his web shop. Such observations were common in the families and in general many of the eFlex pilot users had extensive technical skills. In a survey that Antropologerne made among the 119 households (89 answered), 24% of the pilot users identified themselves as the user profile 'the technical'. This was one out of five user profiles that had been made on the basis of the anthropological fieldwork and the users were asked to place themselves in the category they believed described them best. The other four profiles were 'the economical', 'the curious', 'the participating' and 'the comfortable'. 'The technical' were all male and often engineers or had another technical background. They were among other things described as being interested "in mechanics and/or new technologies, are often frontrunners and are willing to try out new things" (Antropologerne, 2012: 50). They were more technological savvy than most and had extensive knowledge of the energy system as well as 'smart home' use experience. Several of them already had some sort of 'smart home' systems in the house, such as

IHC lighting control or they were involved in electricity production themselves by having installed solar panels or had a share in a locally-owned wind turbine. They often took a keen interest in the functioning of these technologies – or planned to install them themselves, such as the user Flemming who had bought two m2 of PV solar panels, which he wanted to solder together and install on his roof. Often, the users were engaged in DIY projects in the home. The user Jens, for example, made an intelligent heating and electricity system in his house, but also found it inconvenient that the house's in-built vacuum cleaner system did not have an on/off button on the handle of the hose, so he made such a switch by using the remote control for a car alarm. As heat pumps and electric cars are still not widespread in Denmark, the eFlex users were early adopters of these technologies and they had moreover become 'expert users' of these technologies.

Innovative uses and short circuits

Many users seemed especially dissatisfied with the way the heat pumps were optimised. The rationale behind the eFlex project was that the flexibility concerning heat pumps should be taken care of by DE – ideally in such a manner that the households would experience no comfort loss or any sort of hassle connected to providing the flexibility. However, many pilot users clearly expressed a desire to take a more active part in the system, as we saw with Benny and several other users such as Hans, who would turn his heat pump off between 10 pm to 2 am and take advantage of the kickback effect, similar to his freezer experiment.

Some users even made actual short circuits to the eFlex relay box to improve the way their heat pumps were optimised. For most of the heat pump types, DE had two ways of optimising through the relay box: either allowing the air temperature in the house to drop, but maintaining production of hot water, or stopping the heat pump completely – and there was a relay for each function in the box. The user Henry, however, thought the first option would not provide him enough savings, so he short-circuited one of the two relays, so the heat pump would always shut off completely during optimisations. As he explained:

Figure 1. Jens observed that DE often only optimised his heat pump once a day, so he made an electric hob that allowed him to optimise twice a day.

> You just unscrew the lid of the relay box and put a cord between the two legs of the resistor… It has been discussed on PODIO and I can see that several others have short-circuited the resistor just as I have.

Similarly, Jens made an electric hob that allowed him to optimise twice a day.

Another example was Martin: Power nodes did not have ground connections at the beginning of the project, so the users were not able to safely connect refrigerators etc.:

> So I made an extension cord that coupled the ground connection around the unit itself, and then I posted it on the net and said, well, here I have a solution.

This self-made solution, however, was not allowed, and DE introduced instead power nodes with earth connections[4]. Often the pilot users also had many more ideas for the improvement of the equipment, e.g. that the power nodes should also turn off automatically when the HP was turned off.

Users 'tap into' companies

In lead user literature, the user is seen as a source of information for firms, who can tap into their innovativeness to produce breakthrough products. However, in the eFlex project the opposite process also became evident, as several users had entered the project to learn more about smart grid development and 'harvest' the knowledge and network that was created and facilitated by DE. The eFlex user Flemming had, for example, bought his electric car to get some experience with the car and had a business plan to develop intelligent charging solutions for the smart grid. He had volunteered for the eFlex project among other to learn and

> to meet someone and get some experiences with it [flexible charging etc]. That, for sure.

Innovation in a Family Setting: Conflicts and Barriers

In the following I will present my findings concerning some of the conflicts and barriers I observed in the families relating to participation in the eFlex project. Of course, in some families there were no actual conflicts and in those families where there were, the picture was varied and the reasons for conflicts were many-faceted. However, three themes will be presented here.

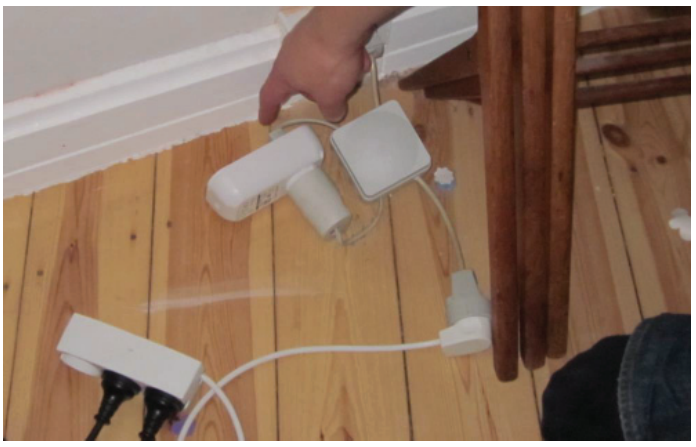

Figure 2. Martin's homemade ground connection for power nodes

Loss of control & equipment designed for one person

The affordances of the equipment did not support a collective domestication and shared use in the family (see also Antropologerne, 2012 on this), *but* at the same time, the equipment was tied up to the electricity system, which the entire family was dependent on. Often it was only one person in the home that was "running around with this iPod" and had free access to the portal 'control room', which meant a loss of control for the other family members. As one wife, Christina, expressed her frustrations:

> Now you have this DONG gizmo, so now nothing is on anymore, so when I get up in the morning and need to turn on the lights in the children's room, that damn device, it has meant I cannot turn on anything…

This naturally limited the sort of experimentation that was possible for the pilot users, as Flemming acknowledged:

> But it's also… I really don't dare do so much. Because whenever I do something, it turns off the DVD or the TV and then they all go crazy! So, it's kind of limited how much one dares to do.

Visualisation and surveillance

This sort of 'dominance' that the pilot users exerted could also be related to the visualisation and surveillance of electricity consumption, which the equipment allowed. The eFlex users could gain some insights the other family members could not to the same degree. This meant first of all that already ongoing negotiations about what was in the first instance meaningful to use energy on were sparked into life. Many spouses had different ideas about whether lighting in the garden or in unoccupied rooms was important, or about what the comfort temperature should be in the house. Secondly, the visualisation feature also allowed the surveying of what other family members were doing at certain times and places, which had obvious implications for the power relations in the family. As one wife said jokingly when her husband showed her the portal, "so that means I can actually go in there [portal] and see, if you are doing anything…?" Not surprisingly, many of the children in the families refused to have any power nodes in their rooms[5].

Interruption of practices and structural barriers

Remembering that energy consumption happens in the course of performing 'time-and-place bounded' practices, which are often tightly coordinated in everyday life, experimentation with *flexibility* also resulted in conflicts, because other family members' performance of practices was disrupted. In Benny's story, we saw for example how flexibility with the heat pump interfered with Marie's washing-up practices in the kitchen. And as we saw in Peter's story, Charlotte was critical of the idea of postponing the dishwasher or laundry to night-time, because this manoeuvre would mess up her planning. She did not have time to hang up the clothes in the morning, which was a time slot that was filled with other practices that took up her time. This was a problem mentioned by many of the eFlex users' wives. Another example was Hans's wife Liv, who thought that his experimentation with night-time washing interrupted their son's sleeping:

> Hans: But in reality we haven't done much to investigate if it is a problem; there are doors in between and if we close the door, then…
> Liv: Really, Hans, if he says he can't sleep because the washing machine is centrifuging, then surely I believe him… I don't have to investigate anything!
> Hans: No, but what I mean is that we have not really done anything to find out if there is a problem and if we could find a solution…

Such considerations for the life paths of others, which hindered experimentation activities, did not have to be conflictual, as in Martin's case. He stopped experimenting with making profiles for the refrigerator to turn off during the day when his wife went on maternity leave and would suddenly stay home all day.

Experimenting with flexibility also clashed with structures or time-bound practices performed outside the home. Martin mentioned how his ability to be flexible with charging his car also depended on his working hours and congestion patterns; with his type of battery, if he were to take full advantage of the cheapest electricity prices in the early morning hours, he would have to postpone the time he left in the morning. Conversely, that meant he would run into another problem of travelling peaks and congestion. The user René similarly expressed how flexibility with laundry not only depended on their 'willingness' to do it, but also on the temporal patterns of their sons' leisure activities:

> When you're a family with children, then you have to do the laundry… The kids have to play soccer tomorrow, their clothes need to be dry.

Discussion

The above findings illustrate that if we are to better understand the dynamics related to the innovative users, we have to take the specific context in which innovation occurs into consideration. As I have shown, householders adopted and adapted the eFlex equipment "to their local conditions and the particularities of their houses and everyday practices" (Hyysalo et al., 2013b: 491). In other words: the users did not experiment in isolation, they were part of a system; the moral economy and practices of the families as well as the material 'particularities' of the house – e.g. size, insulation degree, number of rooms, built-in appliances or accessible power plugs, piping, types of radiators or floor heating, buffer tanks – also had agency (Latour, 1992) and had 'a hand in the innovations' simply because they were all constitutive in defining uses and assigning meaning to the eFlex project. They had an influence on the practices the equipment interacted and co-developed with, and thus on the types of innovations that were meaningful or even possible at all.

This point is addressed to the user innovation literature, which from an S&TS and social practice theory perspective could be enriched with insights regarding how products are always part of networks and social practices, but it also has obvious empirical implications if smart grid stakeholders will eventually take the innovative capacity of users into account.

As Hyysalo (2009) is arguing, other approaches are needed to complement the otherwise dominant focus on the economic rationale behind user-innovation behaviour, i.e. that innovations are seen as the result of individual users' rational decision making, where they weigh up benefits (e.g. use, enjoyment etc.) and dis-benefits or cost (often not monetary).

Although it is emphasised in the literature that benefits can also be things such as enjoyment or learning and although frameworks rooted in for instance creative psychology have been brought in recently (Faullant et al., 2012), the focus is still on *individuals* and the resources they can draw on – whether inner resources or outer resources such as user-communities. Thus, from an S&TS perspective, the dominant focus in user innovation literature on inherent motivational factors and skills of individuals could be supplemented with a focus on the socio-material system and situated context in which innovation happens. In short, a new set of questions related to why (and where) users innovate and what other factors than the 'innovative mind' are at play for the result, are needed.

There needs to be attention as to *how or why* the use context has a bearing on the innovations. The last 30 years of S&TS research have pointed to how innovation is part of a network, and that doesn't change because the innovator is a user – the sticky information does not just reside in his or her head but in the system of which the innovation is part. A user will perhaps be able to point to new product ideas and solutions based on the needs he has already encountered in his context, but, again, needs are not static or predetermined, but co-develop with the system, and innovation happens as a result of a situated interaction (Suchman, 1987).

A more contextual and 'systemic perspective' on sticky information would perhaps be beneficial. It would be interesting to pose more questions about sticky information that are not just about how costly it is to transfer, but about 'what it is' and does a lead user have 'free' access to it? In relation to theories about innovative users: Are the dynamics concerning why, how, where and what 'drives' certain innovations answered by focusing on, for instance, individuals' expected benefit? A more in-depth engagement with "practices and community dynamics of users" is also what Hyysalo (2009: 254) is calling for in an article on micro-innovations in sports industry development. He emphasises the importance of looking at how the collective user community takes part in reproducing but also changing 'kayaking' practices for which the lead users make innovations. In his words:

> Lead users are like citizens of the ancient polis of Athens: a competent, willing and visible elite who are easily seen to constitute the relevant sphere of action. But analogous to Athen's democracy, without the means to pay sufficient attention to the majority of its inhabitants – peasants, women, slaves and foreign merchants – our view of user innovation would miss important issues if the, less grandiose, inventive inputs of other-than-lead-users were neglected. (Hyysalo, 2009: 254)

When dealing with the innovative user, we should therefore also deal with his or her 'fellow' carriers or practitioners and the continuous and collective development of the practice the innovation is part of – all carriers of practices are in a sense innovators as well as producers and consumers at the same time (Pantzar & Shove, 2010). In the case of innovations to a product such as a 'smart home energy management system' it would definitely make sense to consider the context of the household or family of the innovator: they also use and depend on the system, which is subject to innovations, and they take part in developing the practices the system becomes part of and for which innovations are made. User innovation research has only explored user innovations that occur in the context of everyday family life by

survey (von Hippel et al., 2012) and hence has not addressed how the specific socio-material configuration of each household and the network of meanings, materials and practices the innovator is situated in matters for the innovative processes 'on the fringes'. In short, no attention has been focused on innovations *in* more complex webs of artefacts and meanings than just a user-product relation. More attention is also needed regarding innovations *to* networked systems such as the eFlex smart home equipment. A discussion of the latter and its deep entwinement with domestic practices comes next.

eFlex system and energy is an element in many domestic practices

The many conflicts and considerations that have been described in the findings were related to the large number of domestic practices that the eFlex system interacted with, which conferred special challenges for 'the eFlex innovators'. More specifically, the many practices presented a challenging context for experimentation and innovation for two reasons: firstly, because they were 'hung up' on a networked system in the home (the smart home equipment connected to the energy system) and, secondly, the everyday lives of families are already challenged by 'coupling constraints' between life paths and practices, which the eFlex users' demands for experimentation with flexibility did not ease.

The eFlex equipment was tied up to the energy system of the house and thus figured as a material element in many practices performed by all members of the family. It seems self-evident that innovations to a *shared* system with many users will confer negotiations and accordingly have implications for the innovative processes. Such implications do not come into light if we only study innovations to single products, which currently seem to be the focus in user innovation literature. However, the users' experimentation in the eFlex project came to have quite a literal influence on other family members' performance of practices. For example, Marie clearly resisted her husband's participation in eFlex and the results the low-temperature water had for her heat comfort and her ability to bake cakes and wash her dishes. Other examples such as Christina's opposition to the interruption of her child caring at night, or Flemming's family, who went 'crazy' when his experimentation interrupted their TV watching, illustrate the pervasiveness of practices and domains that are related to the home's energy system and thus involved in experimentation with such smart home systems.

Life paths and coupling constraints – many practices and many considerations

Concerning the second issue, the positioning of practices in time and space also had implications for the experimentation that could be done with flexibility. In a practice theory perspective, daily rhythms are "achievements of coordinating and stabilizing relationships between practices" (Shove et al., 2009: 10). For example, 'doing the laundry' may be a project that consists of a closely related bundle of practices, i.e. a practice of washing clothes and a practice of tumble drying or hanging up clothes. Dislocating the washing practice in time has therefore implications for this and other 'bundles' of practices and their coordination: Charlotte opposed washing clothes at night; she was afraid the clothes would wrinkle if lying in the machine nor did she have time to hang the clothes up in the morning. This was an issue raised by many (often wives of) eFlex users, who would for example spend time in the morning getting the kids ready for school. Washing and drying clothes is often done successively, and separating

the practices and introducing a timeslot for hanging up clothes in the morning instead of in the evening was not easy – it conflicted with other practices that were scheduled in the morning. Conflicts and considerations in relation to flexibility experimentation were also related to the previously mentioned 'coupling constraints': Change or dislocation of a practice – for instance delaying family dinner – can impinge on several individuals' paths, as a practice can be a 'node' that several paths run through. In the eFlex study it seemed that the more actors – e.g. children and pets – there were in a household, the harder it became to be flexible with practices (see also Nyborg & Røpke, 2013; Nicholls & Strengers, 2015). Finally, constraints on experimenting with flexibility were also related to how domestic practices are structured or tied to systems or practices external to the household, as we saw in the case of René and Martin.

Conclusions

In this article, it has been shown how the quite simplified – but dominant – portrait of the 'smart grid user', whose relationship with energy is framed solely in terms of his or her role as *consumer* of it (Strengers, 2013), and who uses and understands technologies in an expected and uncomplicated way, misses an important part of the picture.

Households are so far an unrecognised source of innovations and ingenuity when it comes to developing a low carbon energy system, and users certainly display a desire to "exercise control over the consumption process" by employing skill and mastery in humanizing and "creative acts of self-expression" (Campbell, 2005: 24, 27). Although there was probably a higher concentration of 'lead users' among the eFlex users than in the general population, the point remains clear: users are everyday inventors of both the technologies and the practices these are part of, and they can and do play an important role in the development of large provision systems. As Hyysalo et al. (2013b: 490) write in one of the few papers that engage with this issue:

> the inventive user can speed up the development and proliferation of distributed renewable energy technologies [...] through their alternative designs.

Instead of keeping supposedly 'ignorant' publics out of the development process "they should be seen as valuable and generative to the innovation of smart grids" (Schick & Winthereik, 2013: 96). The interpretive flexibility of the smart grid is still great, and multiple roles for the householders can be constructed – e.g. the 'innovator role' that has been sketched out here. Continuing the same policies and scopes for user studies, which reproduce an old notion of the 'demand side' (Wolsink, 2012; see also van Vliet, 2002), may lose sight of the negative energy impacts the 'consumer role' could have (Nyborg & Røpke, 2011).

Furthermore, the S&TS research provides a better understanding of "how and why new products and technological infrastructures are acquired and how they affect practices as they are absorbed into everyday ways of living" (McMeekin & Southerton, 2012: 357) – and consequently better enlighten innovative processes 'on the fringes' of the smart grid field. The previous discussion illuminates the network of practices and systems the eFlex equipment interacted with, which complicated the innovative processes. Moreover, the discussion also underlines how flexibility from households is a complex matter that involves quite a lot of considerations and inter-related factors. It points to how taking on the 'flexible consumer role' depends on more than

'willingness' or motivational factors. Thus, a stronger S&TS focus would deepen our knowledge of the role that users or publics have in constructing certain sustainable transition pathways and support the basis for making policies that to a higher degree fertilise the dispersed creativity of users.

Lastly, the fieldwork demonstrated the need to promote a far more 'user-driven' roll out of heat pumps and other small-scale renewable technologies as opposed to the current technology-driven process and the 'one-size-fits-all' logic. As Hyysalo and colleagues (2013b: 490) are arguing:

> It appears that supplier models do not cater sufficiently for the variation in users' homes, which leaves unexplored design space for users to focus on.

Thus, there is room for users to innovate on e.g. heat pumps to make them more user-friendly for the entire family and more suited to different and varying contexts. Just as user-oriented innovation methods are being used to increase the value of many other products, it would perhaps be beneficial for heat pump producers to integrate innovative users more in the development of these technologies. However, as I have argued in this paper, when involving innovative users we should remember also to talk to an entire household just as the eFlex project did – both to explore the 'validity' of the innovative users' concepts, but also to be inspired by the inventive inputs of other-than-lead-users.

By taking such ideas into consideration, we can hopefully expand the current narrow focus on the relatively high private financial investment in a heat pump to explain why Danes are not taking up heat pumps in the speed that policy makers and producers had imagined (Catalyst Strategy Consulting, 2013).

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Notes

1 There is not one unified 'practice theory' and practice theoretical ideas are represented in a range of disciplines such as philosophy, cultural theory, history, sociology, anthropology and S&TS. Instead, practice theories constitute "a rather broad family of theoretical approaches connected by a web of historical and conceptual similarities" (Nicolini, 2012: 1). However, the philosophers Andreas Reckwitz (2002) and Theodore Schatzki (1996) have developed a rather coherent approach to the analysis of social practices, and the practice theorists referenced in this paper have more recently built a somewhat distinct understanding of the dynamics of social practices related to fields such as energy consumption and the design of ordinary products in everyday life.

2 In a smart grid context, the concept of the 'prosumer' (Ritzer, 2014; Toffler, 1980) has been widely adopted. Originally, the prosumer was characterized as a person who takes part in producing something that they consume, content on the internet being a classic example. According to Ritzer (2016), the concept overlaps with the older, more familiar idea of a 'do-it-yourselfer'. The 'prosumer' notion is used rather inconsistently in relation to the discussion of the smart grid to signify a new, more 'active' type of consumer in the energy system, who takes part in renewable energy production through micro-generation technologies such as photovoltaic cells and micro-wind power. The prosumer in the smart grid thus also breaks with the passive consumer paradigm, but they are not necessarily characterized as particularly innovative.

3 Many users were confused about what the primary aim and intended use of the power nodes was. Whereas DONG Energy had mainly included them to support increasing 'electricity awareness', many of the householders had gotten the impression they were mainly supposed to use them for flexible consumption. This was a type of use, which the design of the equipment did not support very well and accordingly it required quite a lot of inventiveness to find ways to actually use them for flexibility (see Nyborg & Røpke, 2013 for more on this).

4 Companies' challenges in terms of working with inventive or creative users are well known and discussed in e.g. Berthon et al., 2007. User alterations to different aspects of the 'electricity hardware' in a home, e.g. power outlets etc., is dangerous and is inhibited through safety regulations, which probably makes the utilisation of consumer creativity more complicated in this area.

5 Such "digital panopticon" effects are known from elsewhere as an almost inevitable part of automation (see e.g. Grimpe et al., 2014; Hyysalo, 2007).

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APPENDIX 1

Table 2. A summary of the 11 households that were interviewed by the author. Besides the six examples of user innovations below – which includes 'innovative uses' that greatly improves the functioning of the technology to fit the users' needs – and the innovations that "Henry" and "Jens" made, 'actual' user innovations were observed in three other diaries; these included a user putting extra insulation on the heat pumps' tubes, a user building an electric car from scratch and a user working on designing an IT-solution to survey and control the energy consumption in the home. However, many more eFlex pilots were involved in activities that could be described as craft consumption – as creative and somewhat 'innovative' activities; they were, for instance, often active DIY enthusiasts who renovated the house themselves or made elaborate repairs to products in the home. Also, many householders displayed 'lead user characteristics' although no actual innovations were evident in their field diaries. As user innovations were not originally in focus when the interview guide was designed, the observations below are not necessarily 'representative' of the actual amount of user innovations that were made in the households, as we may not have detected them all. Moreover, as stated in the methodology section, the 'lead user status' of the users in this paper is not verified according to conventional methods.

Nr.	Household	Housing – type	Heat pump, electric car or 'ordinary' household?	Examples of activities indicating 'lead userness' – not just related to eFlex product categories
1 (Loop 1)	Father: IT system developer in private company (42). Mother: Nurse (40). Two boys (8, 11).	Detached house with a garden	Air-water heat pump	None observed
2 (Loop 1)	**"Peter & Charlotte"** Father: Entrepreneur (46). Mother: Logo designer (47). Two boys (14, 17). A golden retriever.	Large villa with a garden	'Ordinary' household	Peter is doing programming to improve his web shop.
3 (Loop 1)	Father: IT consultant in private company (38). Mother: Senior position in an energy company (39). A boy (3) and a girl (6).	Detached house with a garden	Ground source heat pump	None observed
4 (Loop 2)	**"Flemming"** Father: Electronics engineer and entrepreneur (49). Mother: Stay-at-home-wife (49). A girl (12) and a boy (15).	Detached house with a garden	Electric car	Flemming is working to develop a new type of charger for electric cars
5 (Loop 2)	Father: Engineer, venture capitalist (49). Mother: Engineer, employed in husbands' company (49). A girl (9) and a boy (13). An au-pair girl.	Large villa with a garden and a swimming pool	Electric car	None observed

Table 2 cont.

Nr.	Household	Housing – type	Heat pump, electric car or 'ordinary' household?	Examples of activities indicating 'lead userness' – not just related to eFlex product categories
6 (Loop 2)	Husband: Pensioned from an office assistant position in a municipality (66). Wife: Office assistant in a municipality (62).	Detached house with a garden	Ground source heat pump	The husband is a passionate amateur-gardener and made a self-build, movable trash bin for garden waste made from an old pram.
7 (Loop 2)	**"Martin"** Father: Authorised electrician, studying to become electrical power engineer (28). Mother: Tailor, entrepreneur (28). Two girls (a new-born and 3).	Small flat	Electric car	Martin is dissatisfied with eFlex power nodes – made a ground connection on them himself. He is currently also rebuilding a gasoline car into an electric car.
8 (Loop 3)	**"Hans & Liv"** Father: engineer, works with renewable energy in large energy company (54). Mother: Manager in a pharmaceuticals company (47). Two girls (9, 15) and a boy (18).	Detached house with a garden	Ground source heat pump	Hans is dissatisfied with power nodes and experiments with new uses to improve flexibility. He is also dissatisfied with the heat pump optimisation offered by DONG Energy and improves it through innovative use. Siv was dissatisfied with information on the eFlex portal and made Hans make an alternative visualisation of electricity prices on paper to place around the house.
9 (Loop 3)	Father: Operational planner officer in the municipality (39). Mother: Physiotherapist, consultant in private company (36). A girl (2) and a boy (4).	Detached house with a garden	Ground source heat pump	None observed
10 (Loop 3)	Husband: Retired, previously constructional engineer (67). Wife: Retired, previously upper-secondary schoolteacher in biology (67).	Detached house with a garden	Ground source heat pump	None observed
11 (Loop 3)	**"Benny & Marie"** Husband: Retired mechanical engineer, now part-time IT consultant (66). Wife: Retired teacher and nature guide (62).	Detached house with a garden	Ground source heat pump	Benny is dissatisfied with the heat pump optimisation offered by DONG Energy and improves it through innovative use.

Architecture as a Science:
Boundary Work and the Demarcation of Design Knowledge from Research

Monika Kurath

Recent STS literature has described a trend of academisation in higher education and universities in which administrative bodies and formalised practices like evaluations have gained increased influence. This article discusses the impact of such trends on the discipline of architecture, focusing on the strains and boundaries that architectural faculties face in their research and teaching practice. Specifically, the development of design knowledge from individual and multiple theoretical and methodological approaches, the tight connection with tacit knowledge forms, as well as the use of non-formalised tenure and peer-review indicate on-going processes of *boundary work* (Gieryn, 1983), where external disciplines evaluate architectural knowledge production and demarcate it from their own research approaches. Due to the increased meaning of evaluations, such boundary work plays an increasing role in framing the form and content of design research. In this respect, architectural research becomes a matter of negotiation that not only involves architecture, but also traditional research disciplines as well as the added restrictions of interdisciplinary and administrative bodies.

Keywords: design research, boundary work, economisation of universities, higher education, epistemic culture

Boundary Work, Academisation and Epistemic Cultures

> Architectural design research depends on intuition, ideas, ideology and individual personalities who create new things that imprint the built environment. Additionally, it engages arts and the humanities. Architectural design combines pure and applied research at almost every step. (Excerpt from an evaluation report of a Swiss architecture department, 10 January 2013)

The above-mentioned quotation illustrates an example of *boundary work* (Gieryn, 1983), where an external evaluation committee has been involved in framing architectural design knowledge as research. The boundaries are drawn in several respects and are concerned with the content of the design practice by referring to the basis of architectural work as intuition, tacit knowledge and individuality. Further boundaries are drawn on a formal level, by identifying the disciplinary rooting of architecture in both the arts and the

humanities and by a twofold location of its research in 'pure' and in 'applied' research.

Gieryn (1983) uses the term boundary work for describing the practice of demarcating science from other knowledge production activities. He shows that scientists have an interest in distinguishing their field specific knowledge production forms from external ones for achieving professional goals like the acquisition of intellectual authority, career opportunities and the protection of the 'autonomy' of scientific research from external influence (Gieryn, 1983). In showing that these boundaries are flexible, drawn and redrawn according to the respective scientific interests, (Gieryn, 1999) shows that the boundaries are not only socially and culturally constructed, but also *science* itself.

Using Gieryn's (1983) concept, the boundary work emerging in the transformation of architecture into a research discipline in the Swiss higher education system is analysed. This paper identifies the reason for this boundary work in trends described in recent STS literature towards the economisation of universities and an externally imposed process of establishing new science policy steering and management structures (Weingart, 2001; Schimank, 2008). The literature describes these strategies as subsumed under notions such as 'new public management of universities' (Schimank 2005), 'new governance of science' (e.g. Braun & Merrien, 1999; Felt & Fochler, 2010), 'managerial revolution' (Maasen & Weingart, 2006: 20) and a harmonisation of higher education systems.

One of the drivers of this larger process is the European Bologna Reform, which has led to a vast top-down-enacted reformation of higher education and organisational structures of universities in a majority of European countries (Maesse, 2010). The reform has not only contributed to more formalised study program structures and standard administrative practices like auditing and evaluation of research and teaching (Schultheis et al., 2008), it has also framed academic attitudes according to the notion of a 'higher education governance' (Ferlie et al., 2008: 326).

These related trends of economisation, harmonisation and managerialisation of universities, higher education and research —here termed as academisation—has had considerable impacts on academic knowledge production. For example it has created a greater flexibility in appropriating funds and in more efficient allocation of resources, but simultaneously it has also generated greater difficulties in persevering long-term lines of research, as well as privileging mainstream research (Schimank, 2008). Facilitated by the Bologna Reform, the academisation of education and research and its standardisation is transforming knowledge production and education into globally marketable products. Subsequently as a result, the influence of interdisciplinary administrative bodies like university management, science policy organisations, research commissions and councils has increased (Fuchs & Reuter, 2003; Masschelein & Simons, 2012; Muche, 2005).

This externally imposed quest for academisation is further characterised by an increased research orientation in applied disciplines and the trend to frame research in measurable terms, such as the amount of third-party funding and peer-reviewed publications (Felt & Fochler, 2010). While scholarly regimentation and economisation of educational institutions has been described as particularly affecting knowledge production in the humanities and cultural studies (Bollenbeck & Wende, 2007), this trend has had a significant impact on knowledge production in applied, skill-intense and artistic disciplines

without identifiable and distinct research traditions such as architecture and the arts, whose applied and practice-based knowledge production processes are hardly compatible with the audit-oriented criteria of traditional research disciplines (Ammon & Froschauer, 2013; Lesage & Busch, 2007).

This article analyses the impact of such academisation trends on the discipline of architecture. It particularly focuses on the strains and boundaries that architectural faculties face in their research and teaching practice, where external disciplines are increasingly becoming involved due to the growing influence of administrative bodies and formalised practices such as evaluations, which have gained within these academisation trends. The analysis is guided by the assumption that architecture as an applied discipline is particularly concerned by such boundary work, and that these strains and demarcations frame and are framed by the specific character of architectural knowledge production—or the *epistemic culture* (Knorr Cetina, 1991) of architecture.

Based on ethnomethodological analyses of knowledge production in hard science disciplines such as molecular biology and high-energy physics in the context of STS-driven *laboratory studies* (Latour & Woolgar, 1979; Traweek, 1988; Knorr Cetina, 1981), Knorr Cetina (1999) uses the term *epistemic culture* for the specific ways, contexts, arrangements and self-understandings in which knowledge is produced in certain disciplines and academic fields. Knorr Cetina (1999) defined her concept of epistemic cultures as consisting of an *empirical* (methodologies, theories and conceptualisations), an *ontological* (instruments, materials, processes and objects) and a *social* dimension (human interactions of context, environment and researchers in their specialised milieu with fellow workers). In her concept, epistemic cultures are specific ways of knowledge production or 'amalgams of arrangements and mechanisms', which in each specific field define the content of knowledge and how it is produced.

Based on the above-mentioned assumption that the boundary work emerging in the transformation of architecture into a research discipline is framed by the epistemic culture of architecture, this analysis implies a twofold approach:

1. An analysis of the *epistemic culture* of architecture
2. An investigation of the *boundary work* concerning architectural research

The epistemic culture of architecture has been analysed within a review of the available architectural, cultural studies and STS literature focusing on the specific character of architectural knowledge production. This analysis has used Knorr Cetina's (1999) analytical framework to identify the empirical, the ontological and the social dimension of the epistemic culture of architecture.

The boundary work in demarcating architectural knowledge production from science has been analysed with an empirical study. This study has investigated the implications of the European Bologna Reform on knowledge production in architecture with a particular focus on the teaching of design and design research in architecture.[1] The data was collected at a Swiss architecture department. Methods consisted of qualitative interviews with faculty members, administrative staff and students, as well as participant observation at faculty meetings and within design studios.[2]

The next section presents an analysis of selected architectural, cultural studies and STS literature describing architectural

knowledge production. This analysis is carried out along the framework of *epistemic culture* (Knorr Cetina, 1991). Its focus is on the empirical, the ontological and the social dimension of the architectural knowledge production practice. The architectural and cultural studies literature tends rather to focus on questions regarding methods and theories rather than the working process itself, which includes the process of developing design ideas, the use of material objects or methodologies. These aspects have mainly been the focus of the STS-based ethnographies. Furthermore, the cultural studies contributions take a greater interest in architectural design (Mareis et al., 2010; Gethmann & Hauser, 2009; Ammon & Froschauer, 2013). The aim of the following section is to identify how the specific character of the epistemic culture of architecture has been described and will form the basis for the analysis presented in section 3 that addresses the fracturing borders emerging around architectural design research.

The Epistemic Culture of Architecture

In the context of professionalisation processes in the 19th century, architecture was established as an academic discipline and transformed from an informal craft into a formal applied-science profession (Kostof, 1977). In the German-speaking world, architecture mainly became part of the engineering sciences at technical universities. Other institutional settings for training in architecture were art schools and universities and schools of architecture (Kostof, 1977). In its various pedagogical contexts, architecture went through periodic waves of scientisation such as during the design methods movement in the 1950s to 1970s and the digitisation of design in the 1990s (Scott Brown, 1999; Weckherlin, 2013). Since the late 1990s in the context of increased financial tightening at universities, the shift to 'new public management' of universities (Schimank, 2005) and the harmonisation of European higher education systems in the context of the Bologna Reform, the field of architecture has followed another trend towards academisation, marked by an expanded research orientation (e.g. Ammon & Froschauer, 2013).

Even though education in architecture has had a longstanding research component because of its institutional establishment at universities, its traditional orientation was more that of a professional education than that of a science (Kostof, 1977). Due to the establishment of architecture at universities in a polytechnic context, a trend that occurred in most cases in Germany, Switzerland, but also in other national contexts, the applied aspects of a professional education have been at the forefront at those sites (Brain, 1991). Research in architecture has primarily been undertaken by neighbouring disciplines such as art history, sociology, social and human geography, material sciences and engineering statics, rather than by the discipline itself (Heintz et al., 2004). The field's lack of its own disciplinary research was mainly a phenomenon at technical universities in central Europe. This gap is known in architecture and the discourses on research by design can be seen as an attempt to fill it (Geiser, 2008). In the Anglophone community, where more beaux arts-oriented approaches located architecture in dedicated schools or art schools, an academic branch of architecture has been more established (Brain, 1991; Kostof, 1977). This lack of disciplinary research in architecture itself has significantly changed since the late 1990s, when applied disciplines underwent academisation and research activities were

ramped up in those fields (e.g. Ammon & Froschauer, 2013).

In the following section, Knorr Cetina's framework of epistemic cultures is applied to STS and cultural studies analyses of architecture. Sections will draw on the three specific empirical, ontological and social factors that frame the epistemic culture in this field.

Empirical Dimension: Individual References Instead of Codified Theories

The *empirical* dimension of architecture can be framed by an absence of codified theories and methods. Rather than to specified theories, architects typically refer to context devoid individual heuristics of the local and global built environment (e.g. Hauser, 2013). Such heuristics include: the 'form follows function' tenet; historic references to stylistic periods (Baroque, Byzantine, Post-modern, etc.); geographic or cultural areas (East Asia, Middle East, South Asia, Mediterranean, Scandinavian etc.); and varying building types (e.g. religious, institutional, single and multi-family residential, high rise, etc.), as well as contemporary heroic figures (e.g. Ludwig Mies van der Rohe, Frank Gehry, Zaha Hadid and Rem Koolhaas), who are described as playing the role that theories and research concepts do for traditional research disciplines (Yaneva, 2005, 2009; Henderson, 1999; Potthast, 1998). Hence, reference buildings and famous architects are used as sources of inspiration and are cited comparably to codified theories in academic writing of traditional research disciplines (Heintz et al., 2004).

Furthermore the individual, local, and user contexts are described as playing significant roles in the design process. Aerial, area, and neighbourhood photographs, street views, façade elevations, urban models, perspective renderings and the placement of the individual design solutions into a context of non-architectural elements are observed as being used for inspiration, as were façades and arranged post-card visualisations (Potthast, 1998; Houdart, 2008). In these terms, studio work and its inscriptions such as sketches, drawings and prototypes, rather than specific theories, methodologies and concepts are framed as the most important part of the architectural reference system (Henderson, 1999). The reason for the admission of a multiplicity of ideas in architecture is identified in architectural education, which is described as consisting of capacity-building in a number of basic categories, such as art, architectural history and theory, social sciences and environmental issues (Cuff, 1991: 63). Also, the main emphasis in the education of architects is on the practical education in the studio (Heintz et al., 2004), rather than on scholastic instruction. In architectural literature, this situational and context-related orientation is brought in relation to the specific architectural method, which is described as being mainly based on the *example* (Eberle & Simmendinger, 2007).

Scholars of cultural studies, sociology and philosophy of science have drawn distinctions between scientific and architectural knowledge production, mostly based on the contrast of the two ideals of reproducibility versus singularity. That is, while artistic and architectural ideals have been characterised by concepts that include individuality, subjectivity and genius-loci, scientific ideals have been framed mainly by terms like objectivity, reproducibility and the 'search for truth' in a philosophy of science perspective (Heintz et al., 2004; Ammon, 2013; Weckherlin, 2013).

This analysis of the empirical dimension of architecture highlights the perception that there is a lack of a community-wide, shared pool of codified references. To sum up, in architecture, knowledge

production is described as being oriented toward multidisciplinarity, individual situations and contexts. The epistemic culture of architecture is further described as following ideals like individuality, singularity and non-reproducibility and as being based on a variety of insights from different fields, such as the arts, art history, the social sciences and physics. While STS driven ethnographies mainly frame this individual approach as an absence of theoretical and methodological rigour, architectural literature identifies this approach as *the* architectural method.

Ontological Dimension: Artistically Framed Knowledge Production Practices

Most of the studies reviewed for this research have in relation to artistic disciplines described the *ontological* dimension of architectural knowledge production as rich in devices, instruments and materiality. In this conception, the design practice is framed as a nonlinear, volatile process of circulation, reformulation, back-and-forth translation and re-adaptation. These studies have also described such work as consisting of handcraft, writing, material work, transition passages and intuitive factors of manipulating social spheres. They have further depicted architectural work as being framed by ideals such as individuality, singularity, a specific architectural gaze and a talent- and genius-oriented paradigm. Visual representations, as well as tools and objects such as pencil, paper and computers that are used to create sketches, drawings, plans and models have been characterised as being the core or the 'heart' of design work (Henderson, 1999), as the 'manifestations of knowledge' (Houdart, 2008) and as 'epistemic objects' (Ewenstein & Whyte, 2009; Murphy, 2005; Ammon, 2010).

Further studies have tried to elaborate the specific character of design by focusing on practices, materials and genuine knowledge forms (e.g. Henderson, 1999; Houdart & Chihiro, 2009; Hauser, 2013; Yaneva, 2005; Potthast, 1998). They have emphasised:

- handcraft such as drawing both by hand and computer-aided, colouring, gluing, layering, copying, pasting, constructing;
- text in the form of keywords, empirical references such as natural or historical documentation, forms and attributes from art history;
- tools such as paper, pen, pencil, ruler, goniometer, computer, paint, models;
- modelling materials such as wood, cardboard, clay, glass, Styrofoam, plastic;
- transitions in the form of translations, combinations and circular references between different working stages and dimensions such as 2D drawings and 3D models;
- and not least tacit aspects in the form of non-realised designs, rejected ideas, drawings, models, coatings, transformations, reproductions, interwoven processes.

Furthermore, the usage of drafting conventions such as line types, symbols, letters and notes to make designs compatible with others, has been observed in several ethnographies (Potthast, 1998; Henderson, 1999; Houdart & Chihiro, 2009). The design practice is further described as repetitive processing, as re-adaptations, as digitisation, as copying, as cutting and pasting 2D and 3D designs, as back-and-forth translations and as circulating ideas,

as routine gestures, and as reiterative adjustments and skilful operations (Potthast, 1998; Yaneva, 2005). In particular, simultaneous thinking, imagining, drawing, and creation of artefacts and knowledge is described as specific for architectural design (Houdart, 2008; Ammon, 2010).

Further studies have pointed to the importance of visual aspects of the design process, such as concepts of an 'inner eye', a 'sensitive gaze' and the framing of architecture as a 'science of the eyes' (Heintz et al., 2004; Henderson, 1999; Daston & Galison, 1992). Pictures and visualisations are framed as being core communication strategies in design processes. In particular, the specific ways of knowing, seeing and acting have been described as playing an important role, as well as the strong focus on intrinsic concepts such as 'creativity', 'productivity', 'three-dimensional comprehension', 'drawing talent' and 'individual style' (Potthast, 1998; Luhmann et al., 1990; Stevens, 1990; Krasny & Hausegger, 2008; Cuff, 1991: 121).

Several studies have drawn analogies between aesthetic and scientific practices. Based on the description of design as an experimental process of observing, testing, scaling and circulating plans, renderings and models those studies have identified a relation between design studio practices and practices in scientific laboratories (Yaneva, 2005, 2009). Furthermore, parallels have been drawn between the collective and iterative character of the design process on the one hand and scientific and technical practices on the other. Examples of these parallels are the heterogeneity of inscriptions and visualisations as well as the impossibility of ascribing the results to a simple intuition (Yaneva, 2005, 2009). In addition, architectural work has been described as being artistic, scientific and technical in parallel (Callon, 1996).

Hence, the ontological basis of the epistemic culture of architecture has been described as a particular orientation toward skills, handcraft and artistic practices; toward tacit knowledge forms; and toward flexible, intuition-based and non-linear working processes. Furthermore, this section points to a lack of vocabulary in STS literature for describing the ontological dimension of architectural knowledge production and instead has related to scientific laboratories practices, like 'testing', 'probing', 'scaling' etc. In contrast, cultural studies analyses have put a stronger focus on identifying individual traits in architectural knowledge production regarding a specific gaze, translations, circulating knowledge and simultaneous thinking.

Social Dimension: Enculturation Rites and Practice-Based Academic Reproduction

The analysed literature stresses the importance of specific social and contextual aspects in the epistemic culture of architecture (Heintz et al., 2004; Potthast, 1998; Yaneva, 2005, 2009; Murphy, 2005). The social dimension in architectural knowledge production is framed as an integral aspect of disciplinary culture, in which qualification and collectivisation take place in unlimited working hours and in an absolute dedication to the profession. Formalised rites of collectivisation in the education and working practices of architects such as a highly intense, festive and sociable working culture and a 24-hour engagement have been described by several authors (Heintz et al., 2004; Cuff, 1991). In this conception, the identity of architects is seen as being framed by social factors such as a high degree of commitment, a certain amount of isolation from non-group members, cohesion with the group, personal sacrifices, and rituals marking passages at various stages (Heintz et al.,

2004; Cuff, 1991). Furthermore, careers and tenure criteria have been described as being rather informal, as that is the tradition in the polytechnic model (Kostof, 1977), in which architectural professionalisation took place in Switzerland and elsewhere. Here, academic promotion is based on professional excellence rather than on academic qualification (Heintz et al., 2004). This means that design chairs are mostly appointed to practicing architects instead of academically tenured scholars.

To date Cuff (1991) has provided the most detailed description of the 'social dimension' of architectural knowledge production. In her analysis of the education of architects, she shows that schools of architecture play a crucial role in the socialisation process of professionals by promoting specific physical and social settings that provide not only education but also enculturation. In particular, most schools base their educational instruction on three highly socially framed rituals: the *studio*, the *critique* and the *charrette* (Cuff, 1991). The critique is framed as the main form of interaction between teachers and students in the studio; the exercises are established as hierarchically ritualised one-way discussions about design solutions given by the teacher and received by the students (Cuff, 1991). Also in the analyses of studio work, the practice of review and critique has been described as a core social factor in design processes. Critique takes place within the hierarchical structure of the office, led by a senior architect who does not design himself but rather comments on the drafts, and the junior architects who are designing (Potthast, 1998).

At the same time, collaborations on the same hierarchical level at the universities are described as being 'colloquial', 'diligent' and 'bustling', in which everybody is in a state of permanent interaction and attentiveness (Heintz et al., 2004; Potthast, 1998; Yaneva, 2005, 2009; Murphy, 2005). Another specific social aspect of architectural knowledge production is the charrette, the final push before a project deadline. The charrette is described as both a highly competitive but also closely bonding situation, with a 24-hour-a-day, mixed working and party atmosphere, where students dedicate all their time to their projects. In designing they compete with each other, but in parallel give advice and help others where needed (Cuff, 1991).

Also, the design practice in the studios is framed as a highly discursive and interactive process of permanent exchange among team members and with external experts (Yaneva, 2009; Murphy, 2004). Often team analyses of models and plans are observed as taking place in informal settings combining meals and coffee breaks with discussion (Yaneva, 2009: 38). Collaborations between project partners, such as architects, engineers and other experts are also described as highly interactive events using plans and models as a kind of trading zone (Galison, 1997), in which experts from different fields exchange their knowledge (Yaneva, 2009: 158).

Within the social dimension, architecture has been described as a highly cohesive social community that produces its knowledge in a mixture of close collaboration and intense competition with peers. The community educates its members through ritualised 'passage points' such as charrettes and critique. The latter is established as a combination between a conference talk situation and 'peer review' (albeit neither anonymous nor formalised). Much of the training of architects takes place outside of academia within professional elite circles. Once established, a professional architect can return to academia.

This literature review has shown that particularly STS based literature that

normally describes knowledge production in the hard sciences has difficulty in framing: 1) the individual, situational and context oriented; and 2) the tacit technical and aesthetic knowledge drawn from the epistemic culture of architecture. In particular, STS approaches so far lack a terminology to describe situational perspectives, tacit knowledge forms, and skill based epistemic practices like architectural design which differs from hard science knowledge production forms. In contrast architectural and cultural studies literature have put a stronger focus on the tacit forms of knowledge production and the ways architectural work could be theorised in terms of architectural methods and in what way design can be framed as research. This combined analysis has enabled a larger picture on how design and architectural knowledge production has been framed and already points to strains and boundaries in the academisation of architecture, which will be discussed in the next section.

Strains and Boundaries in the Academisation of Architecture

The analysis of the epistemic culture of architecture above captures the picture of an applied, skill-intense and highly cohesive social field that provides knowledge using individual theoretical and methodological approaches and which is rich in devices, instruments, artistic approaches and tacit practices. Based on participant observation and qualitative interviews conducted with professors, administrative staff and students at an architecture department in Switzerland, this section discusses strains and boundaries faced by architectural faculty members in their research and teaching practice due to the process of academisation. As it will be argued here, such boundaries mainly concern the situation that research structures are being built up in a discipline that lacks its own inherent and genuine research tradition — at least a tradition of research that is understood as such by other disciplines. In particular, such boundaries have been observed in threefold respects: They emerge within: 1) the *architectural self-understanding* of its epistemic practice as research; 2) the *external perspective* on architectural knowledge production by traditional research disciplines; and 3) the *institutional processes*, established in context of the economisation and harmonisation of higher education and research.

The analysed department, which is located at a technical university, is one of the largest in Switzerland with more than 30 professors and almost 2000 students. Traditionally, research and teaching were separated. While research is mainly conducted in neighbouring disciplines such as art history, sociology and engineering and led by professors recruited by academic promotion, design is taught as practice-based by faculty members who are employed from the pool of professional elites. This means that they mostly run their own architectural offices outside of their chair appointments at the university. In this system, the design studios are mainly taught by teaching assistants who are young professionals in the funding phase of establishing their own offices and who use their jobs at the department as a safe source of income. This clear distinction between research and teaching has become blurred in the context of academisation processes influenced by the Bologna Reform within the past 10 years. Design and construction chairs have become involved in academic research. Here, research was established out of a practice-based epistemic culture without its own distinct research tradition (Ammon & Froschauer, 2013). This is also

the case with the department analysed in our research.

The following sections discuss the observed boundaries emerging within the architectural self-understanding of its epistemic practice as research (3.1); those emerging within an external perspective on architectural knowledge production by traditional research disciplines (3.2); and those appearing within institutional processes established to economise and coordinate higher education and research (3.3).

The Architectural Self-Understanding

As this section will show, architects differ in their understanding of architectural epistemic practice as research. While some are convinced that even their work in the office qualifies as research, others question the academic status of architecture as such. Among the latter, a senior design professor at the department studied involves himself in boundary work by demarcating architecture from other traditional university's disciplines. The professor, who is a former dean of the department, is well known for his architectural practice. He leads a firm with 150 employees and 10 offices around the globe. In his opinion, architecture is misconceived as an academic field and the discussions over architectural research could have been avoided if architecture — which in his view is a professional education and not an academic one — had not been established at traditional universities, where it is measured in terms of a research discipline:

> Establishing architecture as an academic discipline at traditional universities emerged from a historic misunderstanding. (Professor 1, Swiss university architecture department, 17 April 2013, translated by the author)

A professor for building technologies is of another opinion. This professor has been a former dean of the department as well and leads a mainly local architecture office with 42 employees, in addition to holding his academic chair. In his view, architectural work qualifies as research, however as research that uses individual methodologies:

> For me the discussion is a bit idle. Architects are definitely doing research. They have their own methodology. The only problem is that they are not using quantitative instruments. (Professor 2, Swiss university architecture department, 10 October 2013, translated by the author)

This quotation further shows that the lack of quantitative methods in architecture is seen as a problem. As the literature review, it also reveals the understanding of architects that their knowledge production *is* research and the framing of their own individual approaches as their specific research method. According to the interview partner, architectural research is practice-oriented and less interested in theory or methods. Subsequently, this professor sees the main reason for the lack of contributions in these areas is that the core interest of practicing architects who hold most of the design chairs at Swiss universities is practice and not primarily theory:

> To build and to work in practice is our core interest. In very rare cases publications from architects are theoretical. What is the last relevant theoretical book of a practitioner? (Professor 2, Swiss university architecture department, 10 October 2013, translated by the author)

As another quote from the same interview partner shows, the meaning and distinction of research and practice in architecture appears to be unclear, since practicing architects who hold design chairs are often convinced that the practice in their offices and its reflection contribute to research in their field:

> Our research differs from traditional research fields, which is evident from our publications. It usually emerges from our practice; it reflects our office activities. (Professor 2, Swiss university architecture department, 10 October 2013, translated by the author)

As the literature review has shown, this is a widely shared notion in architecture. Due to this unclear distinction of research and practice, architects themselves are involved in boundary work and demarcate their own research from that of 'traditional' research fields. This is also the case within an external evaluation of the architecture department analysed in 2013 as commissioned by the head of the university. The assessment committee was composed of national and international faculty members in architecture, consisting of practitioners and academic architects. In its final report, the committee demarcated the epistemic culture of architecture from science and technology and classified it as multidisciplinary orientated, containing aspects of science, technology, social sciences and the arts. It further pointed to a lack of empirical orientation:

> Architecture is neither science nor technology. It contains aspects of science and aspects of technology. It contains aspects of social sciences but is less empirical. Some facets of art are present. (Excerpt from an evaluation report of a Swiss architecture department, 10 January 2013)

The struggles of the committee in classifying architecture in terms of a discipline and the difficulties in recognising architectural knowledge production as research produce boundary work in the classification of architecture as having a multidisciplinary focus and a strong practice orientation. The professor for building technologies, the second interview partner here, has also mentioned the lack of empirical orientation where architectural knowledge production has not been based on theoretical coherence and methodological rigour. In his view it is based instead on a widely spread idea in architecture of creating something irreproducible and unique:

> Our University administration asks our department to subsume our research activities under a more traditional focus, as found in the research of art historians, the social scientists and the hard sciences. They all have clear rules and research in those fields is traditionally certified. We haven't cared so much about rules. What we are doing is not reproducible, normally it is unique. (Professor 2, Swiss university architecture department, 10 October 2013, translated by the author)

Furthermore, the validity of design problems as research questions has not been clarified yet within the field, as shown by a growing literature focusing on the potential contents and paradigms of design research and research in design (Ewenstein & Whyte, 2007; Geiser, 2008; Goldschmidt, 1991; Gerber et al., 2010; Weckherlin, 2013), as well as on the specific characteristics of design knowledge (Hauser et al., 2011; Hauser et al., 2013; Gethmann & Hauser, 2009; Ammon, 2013). As the evaluation report shows, the committee has demarcated design research from a scientific research paradigm:

> As the definition of design research is discussed, [...] there is a threat that a strong technical orientation will lead to the misappropriation of a scientific paradigm for evaluation of research in design. (Excerpt from an evaluation report of a Swiss architecture department, 10 January 2013)

Therefore, the committee sees research in design threatened by the application of rigorous technical and science-based evaluation criteria. If such criteria are applied, architectural knowledge production becomes formally identifiable as research also by other disciplines. In this conception, genuine approaches in architecture such as design problems are not recognised as research by external disciplines and the university administration. This external perspective on architectural knowledge production is the topic of the next section.

The External Perspective on Architectural Knowledge Production

As this section will show, the applied and practice-based knowledge production in architecture is hardly compatible with audit criteria of traditional research disciplines. This has led to many challenges around the understanding of architectural knowledge production as research by neighbouring disciplines and granting architecture recognition as an academic field. A further topic for boundary work in evaluations and audits of architectural research by neighbouring fields is the unclear demarcation between research and practice in architecture. As the analysis in section 2.1 and recent cultural studies literature have shown, those strains in the recognition of architectural knowledge production as research particularly have concerned the theoretical, methodological and empirical basis of architectural knowledge production. Here, a controversial discussion of 'theory', 'methods', 'the empirical' quality of architectural work and specific architectural 'research', as well as associated concepts, has been brought to the fore (Krasny & Hausegger, 2008; Hauser et al., 2011; Lorenz, 2004; Schoper, 2010; Ammon & Froschauer, 2013). By discussing the case of a PhD student, this section illustrates boundary work performed by external disciplines in granting architectural knowledge production research status.[3]

In the analysed department academic staff increasingly pursues a doctorate and applies for third-party funding.[4] This is also the case with a research and teaching assistant, whose research has been analysed within the mentioned project. He is a trained architect, who worked in practice after university and has now been working for several years at a construction chair. For two years he has been working on a practice based research project on a design problem, relevant to contemporary questions in construction. This student's PhD project cannot be assigned to any one of the classical research disciplines in the field of architecture, like art history, statics or materials sciences. Nor can it be related to any other discipline in the natural or engineering sciences.

> In fall 2012 he tried to get his research plan approved by the research commission of his department.[5] The commission, mainly composed of faculty members from traditional research disciplines in architecture, like art history and architecture theory, twice rejected the plan but then approved a slightly adapted third version. The commission based its original refusal on the argument that a historical perspective in the analysis is missing.

> The student also tried to get funding with a national research foundation, where the plan has also been rejected. The foundation's research commission, composed of members from the social sciences and the humanities, criticised missing hypotheses and references to current research in cultural studies, architectural theory and design theory, although both external peer reviewers did not mention this absence. Besides criticising some minor methodological details, one referee pointed out that it was difficult to assess the academic record of the research group because no peer-reviewed publications were listed. (Case collected in the analysis of a Swiss architecture department, 12 November 2013)

Such cases are not unique to architecture. They can emerge everywhere where peers from other disciplines have to evaluate external, inter- or transdisciplinary research. However in architecture as it is argued here, the demarcations not only concern the frictions borne out of conflicts with neighbouring and external disciplines involved in the evaluation of research. Rather as the interview and the evaluation report excerpts above have shown, the form and content of architectural research is inherently questioned and demarcated from scientific approaches. Furthermore, the eligibility of practicing architects to conduct academic research is debated. Conducting research projects and pursuing dissertations are new practices at design and construction chairs—at least in the country that is home to the department analysed. Without its own research tradition, hardly any architects are members of research commissions in universities and in research funding agencies and science foundations. Nor are there peers who are familiar with architectural research. Therefore, the boundaries for which this case illustrates are questions like *who* decides which projects can be funded, *what* research is eligible as a PhD project and in general; *who* defines *what* architectural research is and *how* it should look like.

Both the university's internal research commission, as well as the external research commission of the national research foundation criticised the lack of specific theoretical considerations. This shows that traditional research disciplines draw a boundary between the conceptual basis of the proposed research and that of an established research discipline regarding its theoretical considerations. The national research foundation's final decision was not based mainly on the external reviews – usually originating from within the applicant's community – but rather on the evaluation of the mainly interdisciplinary assessment commission. This points to the importance that external disciplines have in framing architectural research compared to internal peers in emerging research disciplines.

The criticism of missing hypotheses and references to current research in cultural studies, architectural theory and design theory points to another boundary that is drawn between architectural and 'real' research; namely again one of formalisation and references. This means that whether a proposed project is considered as fulfilling formal qualifications of 'research', will be accepted as a dissertation in a university department, or will receive funding, depends on whether members of assessment committees can assign the design of the proposed project to criteria that are used in established research disciplines. Furthermore, this case also stands for the consequences that emerge by the absence of a validated peer-review process. Hence, external disciplines are not

able to integrate architectural publications into their criteria of measuring the quality of a publication. In this understanding, again the success of a proposed project mainly depends on the members of assessment committees and whether they can assign formalised scholarly quality criteria to the publications of the applicants.

Institutional Processes

This section will illustrate the boundaries emerging within the institutional processes established in context of the economisation and harmonisation of higher education and research such as tenure procedures, peer review and audit criteria. Concerning the process of tenure, architectural research practices have been demarcated from scientific ones with regard to a lack of standardised approaches. As mentioned in section 2.3, academic promotion is based on professional excellence rather than on academic qualification. As the evaluation committee states in the quotation below, the criteria for the eligibility of young academics for a chair are unclear, and formalised criteria in the form of dissertations and habilitations[6] in tenure processes of design chairs are absent:

> The definition of design research is to be discussed, both for the sake of current efforts within the department and for the purpose of clarifying tenure processes and expectations for junior faculty. (Evaluation report of a Swiss architecture department, 10 January 2013)

In addition to unclear tenure criteria, the evaluation committee also observed the lack of a standardised and validated peer review process. Again, the committee draws a boundary between a formalised understanding of a valid peer review and an informal one. In particular, the cooperative forms of knowledge production in architecture, combined with the ritualised and informal handling of critique during the education seem not to be intended to build up standardised forms of validation. The evaluation committee identified difficulties in the clarification of peer review criteria not only in design research, but also in all areas of research in the department:

> It is important for the department to come to a clear understanding as to what constitutes valid peer review for design research (as well as other forms of research within the department, including historical, theoretical, and technical). (Excerpt from an evaluation report of a Swiss architecture department, 10 January 2013)

In particular, by observing the lack of specific criteria for measuring the qualification of design as research, the evaluation committee encourages the department analysed to develop specific criteria for architectural peer review in international cooperation with other architecture departments:

> The central product is design. To assess the quality, productivity and relevance of this research the department is recommended to come up with specific criteria for peer review in an international league of architectural university colleges. (Excerpt from an evaluation report of a Swiss architecture department, 10 January 2013)

This quotation again reflects the externally imposed quest for auditable, evaluable and measurable research in the context of academisation processes. As the evaluation committee is aware of the difficulties of assessing architectural knowledge

production within this context, it suggests that architecture should develop its own criteria for the appraisal of its research:

> This potential problem suggests that discussions about design research need to involve leadership from the institution outside the department and even from other peer institutions. (Evaluation report of a Swiss architecture department, 10 January 2013)

To overcome these boundaries that have been established by the lack of a discipline-wide shared agreement on standards and criteria for the evaluation of design research, the evaluation committee sees a need to make universities and other peer institutions familiar with the specific knowledge production and research practices in architecture. The excerpts from the evaluation report have shown that the specific character of architectural knowledge production leads to a lack of understanding of architectural research on the institutional level of the university administration and therefore to a demarcation of architectural knowledge production from academic research. To cope with this misunderstanding, the evaluation committee sees a need for international coordination in developing evaluation criteria for tenure processes and peer review criteria for architectural research also in an international cooperation.

Research in Architecture as a Matter of Interdisciplinary Boundary Work

The aim of this analysis was to investigate the restrictions and resulting conflicts that the introduction of academisation processes generate within the multi-faceted contexts and arrangements by which knowledge is produced in architecture. To achieve this goal, it was based on two STS concepts: The concept of 'epistemic culture' (Knorr Cetina, 1999) and that of boundary work (Gieryn, 1983). The first concept has enabled a three-dimensional analysis of the empirical, the ontological and the social dimensions of the specific ways knowledge is produced in the field of architecture and the ways in which this field understands its research, as well as itself as an academic discipline. This multidimensional approach has emerged as helpful in analysing the multi-faceted aspects in which academic knowledge is produced. Additionally, this research into architectural knowledge production in the context of academisation has also unearthed one of the weaknesses in this concept. That is, namely the exclusion of the *institutional* dimension (Cutcliffe, 2001). As this study has shown, the institutional context and its specific embodiment have an important impact on the way knowledge is produced. In this respect, the boundary work concept was helpful, as it has enabled the theorisation of the struggles faculty members face in the academisation of architectural knowledge production by articulating the field's self understanding from internal perspectives, as well as how it is viewed from external institutional processes.

Recent literature in STS has described externally imposed trends to establish new public management structures in universities, as well as the economisation and harmonisation of higher education systems. These trends have led to a quest for academisation in practice-oriented disciplines. This analysis contributes an empirical case that sheds light on the consequences of such academisation processes on the epistemic culture of architecture, which might also be true for other practice-based disciplines. As section

1 has shown, the trend of academisation leads to an increased influence of administrative bodies and formalised practices such as auditing, evaluating, measuring and standardising research and teaching structures in academic disciplines. In section 2, architecture has been described as an applied, skill-intense and socially highly cohesive epistemic culture whose knowledge is rich in devices, instruments, artistic approaches and tacit practices. This has produced a gap between a rich use of devices, instruments and artistic approaches in the design process and 'theory' that is mainly produced in neighbouring disciplines such as art history and sociology.

The empirical material discussed in section 3, has pointed to three areas of boundary conflicts emerging in the academisation of architecture: 1) the architectural self-understanding of its epistemic practice as research; 2) the external perspective on architectural knowledge production by traditional research disciplines; and 3) within the institutional processes established to economise and harmonise higher education and research. In general, the quotations from the interviews and the evaluation report point to the assumption that most of the mentioned boundary work has emerged in the context of a disciplinary transition. Architecture as a discipline appears to be in a transitional phase from a practice based education without its own inherent and genuine research tradition to that of a research discipline. In this transition phase, scholars increasingly start to conduct research in an instable situation where research structures are unclear and the disciplinary development is not yet finalised (Stichweh, 1993; Böhme et al., 1974).

In core areas, such as design and construction research, approaches that are understood as research by other disciplines are not yet established. In this context, the research status of knowledge produced in this field and the eligibility to frame a design problem as a research question are subject of boundary work and demarcations of architecture from science. The demarcation of architecture from science is further drawn along formal issues like research methods, theories, the separation of theory and practice, as well as along the formalisation of tenure and peer review criteria. Further boundaries emerge around the highly cohesive social environment that puts a strong focus on individual talent instead of standardised and validated approaches for tenure and peer-review processes.

The increased influence of academisation processes produces particular difficulties for architecture, since due to its limited research tradition has little representation in research commissions and councils. Those commissions, often composed of members of traditional research disciplines with a restricted understanding of architectural knowledge production, acquire a high significance in the framing of the form and the content of research in architecture. This is the case as they decide whether architectural research projects can be funded and whether a design or a constructional problem is eligible as a research project. Hence, the meaning of research in applied, skill-intense disciplines such as architecture has become a matter of negotiation, involving not only the field itself, but also traditional research disciplines and interdisciplinary and administrative bodies such as research commissions and councils.

As the excerpts from the evaluation report in section 3 have further shown, such negotiations might result in applying rigorous technical and science-based evaluation criteria on architectural knowledge production. As a consequence, knowledge production in architecture becomes formally identifiable as research within traditional academic disciplines

but in parallel might lose its specific character such as its skill-orientation, its tacit knowledge forms, and therefore its strong link with the design process and the architectural practice.

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Notes

1 This project is part of a larger research project that analyses the impact of the European Bologna Reform on the education of aesthetic practices in Swiss architecture, design and fine arts departments (Funded by SNF; grant number 143206).

2 These data were collected at a Swiss architecture department between fall 2012 and spring 2014. Methods consisted of continued participant observations at faculty meetings and long-time participant observation in the bachelor's and some master's design studios and of qualitative interviews. Those interviews were conducted with faculty members, department representatives for research and teaching, and doctoral students. Furthermore, the content of current research projects and dissertations was analysed. The observations were recorded in research protocols, the interviews were transcribed and these documents were analysed, using the method of content analysis (Denzin & Lincoln, 2000).

3 A short version of this case has been discussed in Gisler & Kurath (2015).

4 As an example, at the department analysed the number of architectural dissertations (PhDs) in 2012 was more than twice as high as in 2000 (see: http://e-collection.library.ethz.ch/list/subject? parent_id=465586/, accessed 16.01.2013).

5 All PhD students of the department need to get approval of their projects by the commission before they start their second year of research.

6 This references the German and Swiss system, in which academics are required to write a second thesis – the habilitation thesis – after their PhD to become eligible as a professor.

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Meta-Analysis, Ideals of Objectivity, and the Reliability of Medical Knowledge

Saana Jukola

This paper focuses on the ideals of scientific objectivity as they emerge in discussions concerning meta-analyses and medical research. Stegenga (2011) has argued that meta-analyses fail to be objective because conducting them involves making judgments. I show that his reasoning is based on the so-called procedural ideal of objectivity, which can be questioned: this ideal is unattainable and does not capture some of the problematic issues of medical research. By introducing a case in research on selective serotonin reuptake inhibitors, I demonstrate why the so-called social view on objectivity succeeds better in accommodating 1) the way in which scientific research necessarily involves judgments, 2) the possible risks involved in research, and 3) the influence that the institutional context has on research activities. Adopting this ideal of objectivity helps us better appreciate the virtues of meta-analyses and pinpoint which practices threaten the reliability of meta-analyses' results.

Keywords: objectivity, meta-analysis, medical research

Introduction

In this paper, I shall provide a critical study of the ideas concerning objectivity, bias and reliability[1] that emerge in the discussions concerning meta-analyses and medical research in general. Meta-analysis is a method of synthesizing information from two or more studies by using statistical techniques. The synthesis of evidence is done by collecting a number of primary studies that satisfy the pre-specified inclusion criteria, measuring the effect of interest of each study, and then combining them to produce an overall measure for the studies. (Moore & McCabe, 2006: 598.) In evidence-based medicine (EBM) and policy, systematic reviews - often including meta-analyses[2] - are placed on the top of the evidence hierarchies, which represent the assumed strength of different types of evidence. Meta-analyses are thought to provide more precise information on the effects of treatments than individual studies (Cochrane Collaboration, 2015: 1.2.2.[3]). They are meant to amalgamate evidence in a less biased way than other means of synthesizing studies: while a researcher conducting a qualitative review has to make judgments on the relevance of individual studies and formulate the summary based on her account on the chosen material, the formal rules of meta-analysis are supposed to ensure the objectivity of the process. Thus, results of meta-analyses are considered to be a reliable source of information

for forming policy recommendations and treatment guidelines. Here, the inherent assumption is that knowledge is best produced by following rules that enable "excluding individual [...] judgments from the process" (Douglas, 2004: 461).

This article has two aims. First, I argue that the discussions on the strengths of meta-analyses are guided by the so-called procedural ideal of objectivity. I approach this issue by addressing an article by Jacob Stegenga (2011) who argues that meta-analysis's status as "the platinum standard of evidence" is not warranted since even in meta-analysis, the analyst must make diverse judgments, which might hamper the objectivity of the process. Second, I shall show how the procedural ideal may not capture some of the central issues that the ideal of objectivity should take into consideration in order to successfully guide scientific practices. The argument being that even if meta-analyses did satisfy the conditions of being objective in the sense of excluding the need for judgments, some biases detrimental to medical research could not be removed. In this way, I demonstrate why we need a contextual ideal of objectivity for evaluating the production of medical knowledge.

The use of the concept "objective" is eminently complicated, as recent philosophical (e.g., Douglas, 2004) and historical (e.g., Daston & Galison, 2010) analyses demonstrate. Individuals, modes of inquiry, as well as the outcomes of processes can be called objective. In general, the objectivity of results is thought to be a consequence of the method being objective (cf. Longino, 1990: 62–63). In this paper, unless otherwise noted, I discuss the objectivity of methods: I posit that we call a method objective if it produces results that do not unduly reflect the preferences of actors involved in the inquiry (Wilholt, 2009; Jukola, 2014). Which methods best ensure this, is what debates on the objectivity of science tend to centre on. It is important to note that objectivity is an ideal for research. What this means is that even though objectivity could not be fully achieved, it is still worth striving for (e.g., Resnik, 2007: 52). The fact that a discussion about possible biases influencing the results and the limitations of the used methods is a central part of many scientific articles illustrates that the difficulty of achieving objectivity is widely acknowledged in scientific practice.

Objectivity is prized because the objectivity of methods is seen to be necessary for achieving the goals of science, both practical (e.g., predicting and controlling natural phenomena) and epistemological (e.g., explanation and emancipation from flawed beliefs). In this paper, the focus is on the practical consequences of different understandings of what kinds of practices are objective. When research is conducted in a way that we denounce as not being objective, we assume that it is not rational to base practical decisions on its outcomes. Ziman's (2000: 157–161) discussion of the reliability of research captures this understanding: science is not only expected to produce true results but results that can be utilized successfully. In medical research this is particularly apparent as the results of studies are used for informing practical treatment guidelines.

In this way, discussions concerning objectivity are significant also from a non-academic perspective. Research results can have significant implications for the lives of the public. Because of this, maintaining the public's trust in research is an important reason for striving for objectivity (e.g., Resnik, 2007: 57). Trust in science is partly based on the assumption that research results are not biased. In the case of medicine, eroding trust may have serious consequences if it results in behaviour

such as not vaccinating children against diseases such as measles (cf. Poland & Jacobson, 2011). Consequently, searching for ways and means of weeding out biases and cultivating practices that contribute to objectivity is a central task for both scientists and philosophers of science.

Historical studies of objectivity have highlighted the complexity of the concept. In this article, I do not aim at contributing to historical examinations of objectivity. However, these discussions help one to perceive how different ways of using the concept have justified the preferences for different methods, which in turn possess different epistemic virtues. For example, Theodore Porter (1992) has investigated the history of the ideal according to which following rigid rules helps to secure trust[4]. According to Porter, following guidelines and aiming at numerical description of reality were seen as ways of building trust by giving the impression of the absence of judgments. This was the case especially in those fields that were under suspicion: when members of the group committed to following common rules, they appeared more impartial than what had been the case if the actions had been based on their own judgments (Porter, 1992: 639). Following this ideal that secured apparent impartiality came with a price: as Porter (1992: 645) remarks,

> quantification is a powerful agency of standardization because it imposes some order on hazy thinking, but this depends on the licence it provides to leave out much of what is difficult of obscure.

In the same way, in their study of scientific image making, Daston and Galison (2010: 179) describe how some diagnostic utility was lost when photographs replaced drawings made by expert artists. Even though photographs could depict their object apparently without the involvement of human judgment, they could not illustrate colour or spatial depth. Aiming at objectivity - understood as independence from human judgment - did not secure the best possible employability.

In this article, I shall demonstrate that in a similar way aiming at procedural objectivity in the production of medical knowledge may omit some salient features of the evaluated practice. When we look for the conditions that a research process should fulfill in order to be objective, we should not focus on the researchers only. We also need to consider the institutional context of research.This is something that the concept we adopt should be capable of recognizing. Adopting this kind of a contextual view on objectivity as opposed to a merely procedural one can help us see under which conditions meta-analyses serve as a means of producing unbiased knowledge, and, correspondingly, which practices may undermine objectivity.

I shall begin by briefly introducing the basic idea of meta-analysis and the motive for using the method. In section 3, I present the argument that Stegenga (2011) gives against the high evidential status of the method. In these two sections, I show how the ideal of procedural objectivity seems to underlie both the arguments for using meta-analyses and Stegenga's criticism of the method. Section 4 focuses on evaluating the success of the procedural ideal of objectivity in the context of medical research. By introducing a case in selective serotonin reuptake inhibitors (SSRIs) in subsections 4.1. and 4.2., I show that the ideal does not capture some of the factors that may cause detrimental biases in research. This case serves as a test for appraising how different ideals of objectivity succeed in evaluating current research practices. In this way, the conceptual analysis typical of philosophical

investigations is reinforced with an analysis of actual practices of science. In section 5, I first argue that the conception of objectivity that is adopted should be capable of accommodating a wider spectrum of practices than the procedural view does. I present the so-called social view on objectivity and then argue that the pertinent features of medical research are better captured by this view on objectivity, which 1) offers tools for discerning between judgments that can be taken as acceptable and unacceptable, 2) takes notice of the way in which risks, both epistemic and non-epistemic, are involved in the process of producing knowledge, and 3) pays attention to the way in which the institutional context of research can either improve or hinder objectivity.

Meta-Analysis — What Is It and Why Is It Used?

Meta-analysis was introduced by Gene Glass in 1976 and it is used for bringing some order to acquired results in those fields of research where there are many studies looking into the same topics. The numerous primary studies may result in diverse and even contradictory outcomes while producing huge amounts of data. In social and medical sciences, especially, the information resulting from research is in demand, for policy makers and practitioners need it in order to support decision making and practice. However, because of the volume of research conducted, decision makers cannot explore all available evidence on a given topic. Thus, summaries of research are needed. (Shercliffe et al., 2009: 413–414; Stegenga, 2011: 498.)

The basic principle of meta-analysis is simple: calculating a weighted average of a measured effect of interest. For instance, researchers might be interested in knowing if taking certain medication improves subjects' Hamilton Depression Rating Scale scores. In this case, the meta-analysis would involve measuring the mean difference in the pre and post intervention scores. Stegenga outlines the four steps of conducting meta-analysis as follows:

> Meta-analysis is performed by (i) selecting which primary studies are to be included in the meta-analysis, (ii) calculating the magnitude of the effect due to a purported cause for each study, (iii) assigning a weight to each study, which is often determined by the size and the quality of the study, and then (iv) calculating a weighted average of the effect magnitudes. (Stegenga, 2011: 498.)

As a result of pooling evidence from multiple sources, coherent patterns of interest can be established.

Systematic means of synthesizing evidence are thought to minimize the possibility of subjective biases entering the process, and thus provide more reliable knowledge that could be used to support decision making (Cochrane collaboration, 2015: 1.2.2.). Meta-analysis is hailed as superior since it is considered to make subjectivity redundant in amalgamating evidence by supplying a systematic and explicit method. This conception of securing the reliability of research is related to an ideal which Heather Douglas (2004) calls *procedural objectivity*[5]. The essence of this ideal is that there is a process that "allow[s] for individual interchangeability and exclude[s] individual idiosyncrasies or judgments from processes" (Douglas, 2004: 461). If the outcome of a process is the same regardless of the preferences of the person conducting the analysis, the method is objective and the ensuing results are suitable for guiding our actions.

The procedural ideal can be seen in action also in evidence-based medicine (EBM)[6], in which meta-analyses play an important role. According to advocates of EBM, clinical decisions should be grounded on strong scientific evidence. The idea is that instead of personal expert judgments, decisions could be based on guidelines that are composed by collecting evidence from soundly performed scientific studies, preferably systematic reviews of randomized controlled trials (RCTs) (Timmermans & Mauck, 2005: 19). By offering guidelines for clinicians, EBM aims at "limiting idiosyncrasies in [...] clinical procedures" (Timmermans & Mauck, 2005: 20). Moreover, EBM is thought to provide a scientific basis for public policy (Timmermans & Mauck, 2005: 20–21).

The status of randomized controlled trials as the "gold standard" of evidence in medical research has generated plenty of discussion: for instance, the external validity of the results of these trials is argued to be limited (e.g., Cartwright, 2007; Cartwright & Hardie, 2012[7]). I shall be engaging in this debate only in passing. However, my aim is somewhat similar to the one that the critics of RCTs have, i.e., examining whether an ideal that guides activities is fruitful in practice. As mentioned in the introduction, one reason for striving for objectivity is that objective methods are thought to produce knowledge that can be utilized successfully. Advocates of meta-analyses and EBM seem to consider aiming at the procedural ideal to be the best way of producing unbiased, applicable knowledge. This makes it particularly interesting to study whether meta-analysis satisfies this ideal, and whether the ideal itself is successful in producing knowledge for pragmatic purposes.

Stegenga's Argument Against the Objectivity of Meta-Analysis

Next I proceed to discussing Stegenga's (2011: 498) criticism of meta-analysis as "the platinum standard of evidence". The core of Stegenga's argument is that it is unwarranted to praise meta-analysis for being objective since analysts need to make multiple decisions involving judgments at different stages of the process. For instance, when choosing what primary evidence to analyse, a researcher needs to consider at least the following questions: What methodological quality criteria should the included studies meet? Can study parameters diverge? How can the problems caused by publication bias be solved? The rules for conducting analyses leave space for deciding how to proceed with respect to these questions. According to Stegenga, the subjectivity included in the process is indicated by the meta-analyses that have reached contradictory conclusions on the same hypotheses. In other words, contrary to what the promoters of meta-analysis say, using this method does not free scientists from personal judgments, which means that the procedure is not objective, according to Stegenga. It needs to be stressed that Stegenga (2011: 505) is not against using the method as such, but states that "the epistemic prominence given to meta-analysis is unjustified". (Stegenga, 2011: 497–505.)

As mentioned, judgments are involved at different stages of conducting meta-analyses. Two additional issues discussed by Stegenga (2011: 502) need to be highlighted as relevant to the argument of this paper. The first is publication bias: studies that show positive and statistically significant results are published more often than studies with negative or inconclusive results. This bias affects the results of meta-analyses by limiting the pool of primary evidence. Duplicate publication, namely

that the same trials are published multiple times in different journals, can further skew the picture that the published studies paint of the efficacy of treatments. There are methods[8] for trying to correct the effect of publication bias (cf. Shercliffe et al., 2009: 420; Torgerson, 2006: 95–96), but because analysts differ in how much effort they put in trying to fix the bias the results of their analyses vary, which in turn denotes that subjectivity has entered the process (Stegenga, 2011: 502). Thus, according to the ideal of procedural objectivity, publication bias threatens the objectivity of meta-analyses by introducing a further need for judgments.

The second issue relevant to the focus of this paper is the homogeneity of evidence that is included in meta-analyses. The dominant view is that only evidence from RCTs should be included in meta-analyses. This means that other types of statistical (e.g., cohort studies) or non-statistical (e.g., results from pathophysiological studies) evidence are excluded. In addition, the included studies should be sufficiently similar with respect to subjects, results and interventions (Cochrane Collaboration, 2015: 9.5.1.). As Stegenga (2011: 501) acknowledges, it is justifiable to demand a certain amount of homogeneity from the included studies as the purpose of meta-analysis is to measure a causal relation between the studied treatment and the effect of interest. If original studies are designed to detect completely different effects, or study populations differ significantly, conducting a meta-analysis does not make sense. According to Stegenga (2011: 500–502), however, the objectivity of the process is threatened because of the judgments researchers need to make while deciding which data are suitable to be included in analyses. In addition to the threat that judgments pose to objectivity, the external validity of meta-analyses may be limited by the lack of evidential diversity. Relying on evidence from RCTs while ignoring other types of evidence, such as the outcomes of case-control studies, "risks making uninformed judgment [...] on a hypothesis" (Stegenga, 2011: 501).

To repeat, Stegenga's claim is that despite the guidelines for conducting meta-analyses, diverse judgments are involved in the process and thus subjectivity cannot be removed. This makes it unlikely to achieve the objectivity of the process in the sense that the promoters of meta-analysis strive for. In the next section I proceed to discussing the shortcomings of this procedural view. Later, in section 5, I shall argue that instead of condemning meta-analysis for not fulfilling the procedural ideal, the concerns arising in the discussions concerning the method, its weaknesses and strengths can be taken as demonstrations of the inability of the procedural ideal to capture some of the problematic issues involved in medical research. These problems are better accommodated by the so-called social view on objectivity. It has to be emphasized that the view I am presenting is not to be understood as opposing the concerns that Stegenga raises. Instead, I argue that it would be conducive to approach the issues he discusses with a different ideal of objectivity.

Weaknesses of the Procedural Ideal

The implicit assumptions underlying the ideal of procedural objectivity, i.e., the account that judgments threaten objectivity and thus diminish our chances of achieving results that can be utilized without complications, are 1) that it is possible to conduct scientific inquiry by following a formally specified rule, and 2) that striving for performing a process that does not involve judgments is the best way for making sure that the preferences of involved

parties are not reflected in the outcomes. However, as Douglas (2004) has argued, this procedural objectivity is only one of the senses in which the term objective is used, and objectivity in one sense does not necessarily guarantee objectivity in other senses. Associating the objectivity of science with this ideal is debatable, and several authors (e.g., Longino, 1990; Carrier, 2010; Hammersley, 2013) in social epistemology have argued that the objectivity of scientific inquiry may not be best understood as mechanical application of rules.

Why, then, does the ideal of procedural objectivity fall short as a model of objectivity for meta-analysis and medical research in general? First of all, as is well known, there cannot be formal rules of proceeding for every step of the research process (e.g., Longino, 1990; Wilholt, 2013). Second, even if there were such rules and following them without judgments was possible, some of the problematic issues related to medical research could still not be removed. This will be demonstrated shortly: it seems that controlling biases in producing knowledge in medical science requires something more than striving for amalgamating evidence without making judgments. Next I will present a brief case on research on selective serotonin reuptake inhibitors. By introducing this example, I demonstrate why the procedural view on objectivity does not capture some of the essential issues related to what objectivity should comprise in the context under discussion. The problematic practices that are introduced by the SSRIs example are not specific to research on this type of drug, but to pharmaceutical research in general. Because of this, discussing this case is of relevance to the philosophy of medicine and commercialized research more broadly.

Research on selective serotonin reuptake inhibitors

According to the statistics of WHO (2012), more than 350 million people worldwide suffer from depression. Nowadays the illness is often treated with selective serotonin reuptake inhibitors (SSRIs) that were accepted for use in the 1980s (Lawlor, 2012: 176). SSRIs have become one of the most commonly used drugs in the world (Fergusson et al. 2005). Lately, dissenting voices have begun to question the extensive use of the drugs. Some critics (e.g., Horowitz & Wakefield, 2007) worry that people facing hardships that are an inseparable part of human life are excessively diagnosed as suffering from pathological depression and prescribed medication, others (e.g., Kirsch, 2010) have even claimed that the effectiveness of SSRIs is based on the placebo effect. Here, however, I discuss the debate on the possible side-effects of the drugs.

The discussion on the adverse effects of SSRIs began in the 1990s when stories about suicidal behaviour that was linked to the use of the drug started to appear (Healy & Whitaker, 2003: 332). However, it was not before October in 2004 that America's Food and Drug Administration (FDA) decided that a black box warning should be added on the packages of antidepressants to inform patients about the increased risk of suicidal tendencies in children and adolescents taking these drugs (FDA, 2004)[9]. Therefore, questions that need to be asked are: Why did it take almost 15 years before the risks were officially recognized? Which factors have had an impact on the discussions on SSRIs?

In a recent article Pigott et al. (2010) examined four meta-analyses of the efficacy of antidepressants. All reviewed studies analysed trials registered by FDA before they were started. Thereby, researchers were able to compare published results with the outcomes that could be drawn from

the data sent to FDA. Analyses "document a profound publication bias that inflates [SSRIs'] apparent efficacy" (Pigott et al., 2010: 267). In addition, published studies accentuated positive results for outcome measures that were not pre-specified as primary - or pre-specified at all - while leaving the negative results for pre-specified outcome measures unpublished. (Pigott et al., 2010: 267.) For instance, Turner et al. (2008), who compared data on 12 antidepressants (including SSRIs such as Citalopram, Escitalopram, Fluoxetine and Paroxetine), concluded that negative or inconclusive studies were often published as reporting positive results.

Insufficient reporting of data was established also when Whittington et al. (2004) analysed published and unpublished data on treating depressed children with SSRIs: even though published data gave support for treating children with SSRIs, unpublished evidence suggested not only that citalopram, venlafaxine, paroxetine and sertraline may not be efficacious but also that using the products may involve the risk of suicidal behaviour. Similarly, Fergusson et al. (2005) conducted a systematic review of RCTs to examine the possible connection between SSRIs and suicide attempts. Their result was that there is a "more than a twofold increase in the rate of suicide attempts in patients receiving SSRIs compared with placebo or therapeutic interventions other than tricyclic antidepressants" (Fergusson et al., 2005: 398). According to the authors, the increased risk may not have been noticed in individual studies because of the small trial sizes and the rarity of suicides and attempted suicides. Likewise, the studies analysed by Whittington et al. were not designed to detect suicides. Even though the increased risk of suicidal behaviour would be low, it is a cause for concern at the population level due to the commonness of SSRI-treatment. Fergusson et al. (2005: 399) remark that the duration of clinical trials tends to be short, and thus the long term benefits and risks of treatment may go unnoticed.

David Healy (2002: 259) - one of the most vocal critics of the nonchalant use of SSRIs - has claimed that the financial interests of the pharmaceutical industry played a role in the problems of the drugs being unnoticed. His claim is that since the companies sponsoring trials had similar interests, i.e., reaching outcomes according to which the drugs are safe and effective, the studies were designed in ways that made the detection of adverse events less likely[10] (Healy, 2002: 259). Healy is not alone in claiming that pharmaceutical research might be skewed by commercial interests. For example, Als-Nielsen et al. (2003) examined 370 RCTs to determine if an association existed between the source of funding and conclusions. The study concluded that in for-profit-trials the quantitative results tended to be interpreted more positively, i.e., the tested drug was recommended for use more often, than in other trials. A recent review by Lundh et al. (2012) states that methods of industry sponsored trials may be chosen in ways that lead to results favoured by the sponsors. According to Sergio Sismondo (2008a), the sponsors may influence the outcomes of studies both indirectly and directly. First of all, the prevalence of pro-industry findings could be partly explained by unrecognized obligations that the researchers paid by the industry feel towards their sponsors: their judgments can be influenced by the feeling of needing to compensate for the benefits they receive from their employer. Second, industry employs more direct ways of influencing results. Publication planning, or "ghost management of medical research includes practices such as choosing test subjects, endpoints, comparators, the doses of tested products and comparators, and trial

duration in a way that makes adverse events less likely to appear" (Sismondo & Doucet, 2010: 275)[11]. Also, withholding negative data or interpreting it in a questionable way can be used to conceal side effects. In addition, trials may be prematurely aborted and study protocols altered when the study is already in the making. (Sismondo, 2008a: 1910–1912.) One approximation is that 40% of publications on new drugs have been ghost-managed in this way by the industry (Sismondo, 2009: 172).

Objectivity of research on SSRIs

The published outcomes of the trials on SSRIs painted an overly positive picture on the efficacy and safety of these drugs, which was at least partly brought about by practices that were due to ghost-management. As the discussions on objectivity focus on what kinds of actions best ensure that the outcomes of inquiry are not unjustly influenced by the inclinations of involved parties, the case can be said to demonstrate a violation of objectivity. Next I shall itemize which factors delayed the recognition of SSRIs' risks.

Firstly, as the studies by Fergusson et al. (2005) and Pigott et al. (2010) demonstrate, due to the publication bias, the published data indicated that the products were safer and more effective than later research has shown them to be. Since there is evidence of systematic disappearance of negative data, and since this seems to be connected to commercial interests, we should denounce this phenomenon as a violation of objectivity: the interests of involved parties have unduly guided research towards certain kinds of outcomes. As mentioned above, the existence of the difference between published and unpublished data has been demonstrated by meta-analyses, such as the one conducted by Whittington et al. (2004). However, these analyses can be carried out only if researchers get access to unpublished material. This, in turn, requires institutional practices such as the preregistration of trials. What this means is that exposing the real scope of the bias is also dependent on processes that concern communal practices of science widely understood: structural factors, which are not traditionally perceived as relevant to the justification procedures (e.g., Brown, 2010), turn out to be relevant with respect to checking the objectivity of the process. The availability of produced data, for instance, can hinge on the institutional arrangements of the community.

Secondly, primary studies were too small and short in duration to detect rare adverse effects (Fergusson et al. 2005: 399; Vandenbroucke & Psaty, 2006: 2417). As the promoters of meta-analysis and Stegenga (2011: 498–499) state, this is a problem that meta-analyses can help to correct.

Thirdly, empirical work on commercial research suggests that studies were designed in a way that made it more difficult to detect some of the effects of the drugs: for instance, due to the lack of suitable categories, some adverse events may have been misleadingly coded (Healy & Cattell, 2003; Healy, 2011: 151) and study protocols altered (Pigott et al., 2010). These are evident violations of good scientific practice, and conducting a meta-analysis on the data does not help to remove these biases. Moreover, methodological choices that raise the chances of tested products appearing more effective seem to be connected to the financial interests of the sponsors of studies (Lundh et al., 2012). It is also noteworthy that information on the dubious practices of industry has become available via legal actions involving pharmaceutical companies (e.g., Healy & Cattell, 2003), which highlights the importance that institutional extra-scientific factors have on the conditions for critical activities of science.

If the above approximations of prevalence of ghost-management are correct, a considerable part of published information on treatments is shaped by commercial interests. Even if they followed the ideal of procedural objectivity, meta-analyses alone could not solve the problem of biases as they emerge in this case: if the pool of primary evidence is already skewed, the outcome of the meta-analysis will not be unbiased either. However, they can help researchers to identify that problems exist, for instance by showing how published and unpublished data give rise to different conclusions. Procedural objectivity strives for removing personal biases from evidence synthesis by making judgments redundant. Even if meta-analysis succeeded in this - which it does not, as Stegenga's analysis demonstrates - it could not eliminate the more systematic biases of research. The case of SSRIs also exemplifies how institutional practices that are not part of justification procedures, such as preregistration of trials or legal action, may be needed for making biases or their sources visible. As mentioned, researchers had to have access to unpublished data before they could verify that some of the adverse events had not been reported. In the following section I shall argue that the procedural ideal of objectivity does not accommodate these points, and thus we should pursue a different ideal of objectivity for promoting reliable research.

The Social View on the Objectivity of Medical Research

The procedural ideal of objectivity seems to be both on the one hand practically unreachable, and on the other, insufficient in solving some of the problems of medical research. One of its weaknesses is that it cannot discern between acceptable and unacceptable judgments since judgments *per se* are seen as destroying objectivity. However, since judgments are a necessary part of scientific activities, in order to be applicable to actual practices, the conception of objectivity should be capable of making these distinctions. For example, referring to the above discussed case, the adopted conception should clarify what it is that makes ghost-management problematic.

I have argued elsewhere (Jukola, 2014) that when discussing the objectivity of research in fields with applicable and socially relevant outcomes, we should adopt a view of this virtue that considers also community-level actions and structures: *the social view on objectivity*. This view accommodates the intuition that judgments do not have to be destructive to objectivity while, at the same time, making it possible to discern between acceptable and non-acceptable judgments. Further, this view helps one to understand how non-epistemic considerations can be incorporated into the research process without letting them steer research unduly. According to the social view, judgments as such do not destroy objectivity because, unlike those who praise meta-analysis for its alleged procedural objectivity seem to imply, they are not private and impossible to evaluate by nature (Hammersley, 2013: 63). This means that it is possible to examine whether the decisions made during the course of research have been warranted.

The social view and the need for making judgments

The social view holds that it is not enough that researchers strive for "thinking and drawing conclusions based on strict logical adherence to relevant facts" (Smith, 2004: 152) or following rules to the letter. The social view on objectivity takes as its starting point the realization that, in practice, conducting scientific inquiry always seems

to involve the need for making judgments and choosing between different ways of proceeding. Even if scientists are familiar with the guidelines they are to follow - i.e. they know the rules of the trade - and are willing to adhere to them, methodological conventions do not fully determine how research should be carried out. This is lucidly demonstrated by Stegenga's discussion on meta-analysis. However, unlike Stegenga claims, this does not mean that the objectivity of a process is necessarily under threat.

The question of how to incorporate the necessity of making judgments into our notion of objective inquiry has been comprehensively addressed in recent social epistemology. According to Helen Longino (2002: 184), different theoretical and methodological preferences may lead researchers to apply rules in disparate ways. Whether one finds a given application to be acceptable depends on the views one has concerning the theoretical and methodological assumptions that have given reasons for the application.

James Tabery's (2014: ch. 4 & 6) analysis of a dispute about whether depression is related to the gene-environment interaction between the serotonin transporter gene and stressful life events offers an example of this in the context of meta-analyses. In this case, different meta-analyses on an apparently same hypothesis reached contradictory outcomes due to different background assumptions. According to Tabery, the contradictory results emerged because researchers in different teams had diverging views on how to define the variables of the hypothesis and, thus, disagreed on which studies should be included in analyses. For example, as one team focused only on primary studies that had included cases where individuals had suffered many stressful life events, another team had included also those studies where individuals had suffered one stressful event. (Tabery, 2014: 162–163.) Pointing out that judgments were made when these meta-analyses were conducted does not seem to be a fruitful way of criticizing either one of these studies. In this example, the differences in conducting the meta-analyses seem to be unrelated to non-epistemic interests of analysts, but were motivated by different theoretical assumptions. In order to evaluate the acceptability of the ways in which each analyst applied the rules of conducting meta-analyses, constructive criticism of research would have to heed these assumptions.

In addition to epistemic assumptions, different ways of applying a rule can be based on different understanding of the non-epistemic consequences of research. In her influential paper, Heather Douglas (2000) argued for a way of incorporating value judgments in research in a way that does not compromise the reliability of results. Her discussion is based on the idea of inductive risk: Data never provide conclusive certainty on the correctness of a hypothesis and the rules for conducting inquiry are not binding, and because of this uncertainty, researchers need to ponder what kind of consequences may follow from possible mistakes. Some research projects are expected to have non-epistemic consequences - for example, permissions to market new pharmaceutical products are granted on the grounds of research outcomes. In these cases, conducting inquiry should involve making value judgments concerning which risks are worth taking and which possible non-epistemic outcomes should be avoided. (Douglas, 2000.) Torsten Wilholt has argued for a similar view. According to him, our trust in scientific research is based on the assumption that when methodological rules leave space for judgments, the decisions that are made during research

are "based on the presumption of shared ideas about the values of true results and the dangers inherent in errors" (Wilholt, 2013: 248). In other words, the theoretical and methodological ideas and views concerning the goals of research help to bridge the gap between a methodological rule and its application in a given situation (see also Intemann, 2005: 1010–1011). For criticizing the judgments concerning how to proceed with research, it is necessary to scrutinize the epistemic and non-epistemic assumptions they are based on.

It should be noted that adopting the social view does not mean that one should abandon the idea of striving for following procedures altogether – the ideal of procedural objectivity would just lose its status as the ruling ideal. The social view can very well incorporate the goal of following a procedure as far as possible as a means of counteracting some problems of knowledge production. As individuals are prone to reasoning fallacies, guidelines for conducting experiments and analyses need to be formulated to guard against biases operating at the individual level (e.g., Ioannidis, 2005: 0698; Howick, 2011: 166). In this way, the social view invites the use of communally accepted guidelines, such as the Cochrane handbook, for regulating the activities of individuals. In other words, the social view can incorporate elements of the procedural ideal. However, unlike the procedural view, the social view does not require that a rule should be applied similarly in every situation.

In this case, objectivity does not mean that all researchers have to apply the rules in exactly the same ways or that research is value-free[12]. Does this mean that anything goes? No. What objectivity requires, according to the view advocated here, is that when researchers make the judgments and decisions concerning how to conduct research, they need to consider which way of proceeding would best support the goals of inquiry. Yet, as humans are fallible and prone to biases (e.g., Uhlmann & Cohen, 2007), this individual effort alone is not enough. As Longino (1990: ch. 4; 2002: ch. 6) has argued, a social backup mechanism is needed for auditing the practices of individual scientists, i.e., questioning the assumptions and goals their actions are based on. This means that the institutional practices in communities must enable critical evaluation of different stages of research. Practices that improve the chances of critical exchanges can be labelled as supportive with respect to objectivity and, obversely, factors that limit the possibility of criticism pose a threat to objectivity.

In the case of conducting meta-analyses, the social view holds that researchers need to be aware of the communally accepted guidelines and conventions for conducting analyses (for instance, The Handbook of Cochrane Collaborations, 2015) and do their best in obeying them. When the rules need to be applied, researchers should consider which ways of proceeding best contribute to the aims of inquiry. For example, as Stegenga (2011: 499) remarks, there is a link between the financial ties of researchers and the outcomes of the meta-analyses they have conducted. While both the social view and the procedural ideal of objectivity recognize these incidents as violations of objectivity, the social view offers more tools for analysing these cases. This is because while the procedural view finds the process to be non-objective once judgments are involved, the social view is capable of examining the situation further – and without judging all commercial research to be biased. According to the social view, inquiry is not objective if the decisions involved in the research process have been made for reasons that are not in line with the generally acknowledged goals of research[13]. Thus, if research is conducted in a way that

is motivated by interests inconsistent with pursuing these goals, it can be criticized for not being objective. For instance, ghost-management of medical studies becomes problematic when commercial interests override the concerns for finding the causes of and cures for illnesses. In these cases, it becomes less likely that the produced knowledge can be successfully applied in healthcare decisions. In this way, the social view shows us why some of the decisions made by actors involved in the research on SSRIs can be condemned.

The social view and publication bias

A major issue related to research on SSRIs was that a considerable part of studies was never published. Because it acknowledges the institutional context of research and evaluating practices at the community level, the social view is better at capturing the troublesome features of publication bias than the procedural view. The problematic nature of this bias becomes evident only when research on a given topic is regarded in its entirety - i.e., it cannot be recognized by evaluating individual studies only. In addition, this bias arises as a result of a prevalent communal practice. (Jukola, 2014.) Thus, its features are not best understood from a perspective that focuses on whether individuals follow rules to the letter[14]. The social view can help us identify how the current system of medical research encourages practices leading to publication bias and why this can be denounced as reprehensible: The imbalances between negative and positive outcomes that are supported by choices that have been motivated by interests not in line with the accepted goals of research are clearly reprehensible. One suggested reason for the prevalence of publication bias is that journal editors may be unwilling to publish negative or inconclusive results (e.g., Resnik, 2007). As researchers are working in an environment where the number of publications can make or break their careers, we cannot simply require them to start submitting their negative findings if those are likely to be rejected. However, a recent study found no decisive empirical evidence for the claim that editors were biased against negative studies (Chan et al., 2014). Instead, in medical research, the absence of studies with negative conclusions seems to be connected to financial interests, as was already mentioned. Consequently, new drugs are systematically favoured in industry sponsored trials, which affects the literature in general, and thus meta-analyses as well. (Bekelman, Li & Gross, 2003; Ioannidis, 2005; Sismondo, 2008a: 4; Sismondo, 2008b.)

From the perspective of the social view, publication bias is problematic as it disturbs critical interactions within and between communities. When some data are not published, other researchers cannot properly evaluate the soundness of research outcomes. In addition, replication becomes nearly impossible (Glasziou et al., 2014). Thus, publication bias not only leads to a distorted picture of the object under study, but it also further undermines the conditions for objectivity by violating the openness of research. Also, withholding evidence may increase the need for judgments involving non-epistemic elements: when researchers have to make their decisions on the grounds of less data than would otherwise be necessary, the uncertainties involved increase.

Identifying publication bias as a community-level problem can also facilitate finding solutions to it, and many of the already suggested improvements reflect the spirit of the social view. Even if it is not usually explicitly stated, suggestions for improving the reliability of medical research often aim at improving the conditions of critical evaluation of studies. For example,

in 2004 the International Committee of Medical Journal Editors stated that trials on drugs cannot be published unless they have been registered before the beginning of the trial. (De Angelis et al., 2004). The motivation for this policy was to facilitate the detection of missing data and terminated trials, and thus govern publication bias. There are other suggestions for improving the objectivity of medical research that are perfectly in line with the ethos of the social view as well. As an example an influential paper by Ioannidis (2005) can be mentioned. Ioannidis argues that the body of published medical literature is seriously skewed as a result of the way individual studies are conducted, the prevalence of bias, and the way in which competition between research teams encourages practices that do not contribute to producing reliable knowledge. Ioannidis states that in addition to methodological improvements and adhering to common standards of conducting studies, for improving the situation it is important to evaluate the totality of evidence in a field of research, instead of focusing on evaluating individual studies. Preregistration of studies is one of the measures that can be taken to enable this. (Ioannidis, 2005: 0701.) Likewise, Young et al. (2008) state that the current publication practices distort science: Published results tend to give an exaggerated picture of the state of research because in biomedical research, the few prominent journals have high rejection rates. Because publishing in prestigious journals is a precondition for building a successful career, it is not rational to submit research that is likely to be rejected, e.g., replications of previous work (Young et al., 2008: 1419). According to Young et al., this situation is maintained somewhat artificially, as print page limits can be taken to be an excuse in the current age of online publishing. Digital publication could facilitate the publication of a greater number of articles: those papers that pass peer review but are not considered to take priority could be published online. (Young et al., 2008: 120–121.) The social view explains why these policies can support the objectivity of research. By changing the institutional context of science, such as the publication system, it is possible to improve the conditions for critical interaction and the evaluation of research[15].

The social view and the lack of evidential diversity

The social view not only helps us to identify factors that can bias research, it also helps to scrutinize why the lack of evidential diversity in meta-analyses can be seen as undermining the applicability of results. This is one of the points that Stegenga raises against meta-analysis's high status. According to him (2011: 500–502), the objectivity of process is threatened when researchers need to judge which data are suitable to be included in the analysis. However, as has been argued, we should adopt a conception of objectivity that recognizes how judgments *per se* do not impair objectivity, but that the problem lies elsewhere: the principle of total evidence may be violated when a decision on whether to reject a hypothesis or not is based only on RCTs. There are two diverse reasons for arguing that the homogeneity of included evidence may threaten the reliability of treatment guidelines: First, as was already mentioned in subsection 4.2., there is evidence on widespread bias in medical RCTs. If trials are systematically designed to reach positive results (e.g., Sismondo, 2008a; Sismondo & Doucet, 2010), and meta-analyses do not succeed in filtering out these biases, basing treatment guidelines on meta-analyses of RCTs is problematic. Second, similarly implied when the objectivity of research on SSRIs was

discussed in subsection 4.2, even properly conducted meta-analyses of ideal, unbiased RCTs produce evidence that might not alone suffice to answer some questions with considerable practical relevance.

A motivation for aiming at an objective method is the wish to gain reliable knowledge that does not lead us astray in our actions. In order to achieve reliable knowledge to back up treatment guidelines, evidence on the possible side effects of drugs is needed. According to critics, RCTs may not be able to deliver this information. For instance, as mentioned in subsection 4.2., trials are often too short in duration to detect the effects that appear later during the treatment, and the number of subjects may not be high enough to enable the appearance of rarer effects (Vandenbroucke & Psaty, 2006). As already stated, this is a problem meta-analyses can help to solve by pooling together more patient-level data. Another worry is the representativeness of trials. If the recruited subjects are young and in relatively good health, while the members of the eventual target group for the tested product tend to suffer from several illnesses, the outcomes of the RCT may not offer knowledge that could be applied without complications. (Vandenbroucke & Psaty, 2006: 2417.) As Cartwright and Hardie (2012: 122) state, properly designed and run RCTs are good for evaluating if a certain policy or a drug causes a certain effect of interest in a certain population but they are narrow in scope[16]. Yet another reason for questioning the authority of RCTs on providing evidence on adverse effects is that since side effects are usually unintended, they are difficult to record systematically (Vandenbroucke & Psaty, 2006: 2417).

According to the social view on objectivity, the epistemic and non-epistemic risks need to be considered when methodological choices are made, and the context and aims of research should to be acknowledged when evidence is assessed. Along these lines, it has been suggested that avoiding errors with severe consequences may legitimize setting the criteria of sufficient evidence differently for establishing that a drug is efficacious and for establishing that it has side effects. Since the consequences of accepting a false hypothesis on the safety of a drug can be severe, the constraints on the acceptability of evidence should be "highly flexible" (Osimani, 2013: 457). For this reason, in the case of unintended side effects, collecting and analysing all available evidence, statistical and non-statistical, is a better approach to establishing if a drug has possible negative effects (Osimani, 2013: 459). In a similar vein, Stegenga (2011) suggests adopting the Hill strategy for evaluating medical evidence: Sir Bradford Hill argued that instead of accepting evidence only from RCTs, good arguments on a possible causal connection could be made if separate pieces of evidence support the claim, including, for instance, the plausibility of the suggested causal connection given the existing knowledge of possible biological mechanisms, the coherence between the causal interpretation and existing knowledge, and experimental evidence. The only desideratum necessary for establishing a causal relation is that the cause has to precede the effect. Otherwise, all of the points do not have to be met. (Stegenga, 2011: 504–505.) Particularly in the context where the commercial interests of industry have an influence on how RCTs are carried out, it is relevant to consider how these interests may impact the evidence that is produced, and then, modify methodological conventions of evaluating evidence accordingly (Osimani, 2013: 460). In this way, the risks that are related to research and its consequences can be acknowledged and minimized.

Because the social view allows the possible non-epistemic risks that are involved in research to be taken into consideration, it can help to solve some of the problems that arose in the case of SSRIs discussed in the section 4. According to this view, considering the results of RCTs only is not acceptable if there are reasons to assume that the possible existence of some serious side effects could not be established by them alone. In addition, the social view grants us the view to consider the possibility that decisions concerning how the RCTs were carried out were motivated by interests that were in conflict with generally accepted goals of biomedical research, e.g., finding a safe and effective treatment for an ailment. Moreover, this view acknowledges that conditions for producing reliable knowledge are partly dependent on contextual factors. In the SSRIs case, widely shared financial interest motivated actions that gave rise to serious publication bias, which could be avoided by previously mentioned actions such as preregistration of trials.

Conclusion

I have argued that the ideal of procedural objectivity as the guiding rule in medical research should be abandoned. This is because the ideal, on the one hand, is practically unattainable, and, on the other hand, does not help to evaluate all of the practices that are relevant in producing reliable medical knowledge. The issues emerging when knowledge is produced for solving medical problems are better dealt with by invoking the social view on objectivity. The social view offers us tools for separating legitimate judgments from illegitimate ones, and allows us to take notice of the risks involved in research. In addition, it takes into account the possibility of systematic biases, such as the publication bias.

As was mentioned in subsection 5.1., the social view is not fully incompatible with the procedural ideal. However, the procedural ideal is insufficient in science. Comprehending this and the way in which it may be useful to establish some codes of conduct according to the procedural ideal, helps one to better appreciate the role that meta-analyses have in producing reliable knowledge. Meta-analyses are no miracle tools that can be conducted without judgments. However, the rules for conducting them can be taken as an example of guidelines that curtail idiosyncratic preferences to a certain degree, i.e., methodological conventions that "facilitate epistemic reliance within science" (Wilholt, 2013: 244), but cannot fix all methodological steps. Adopting the social view helps us to see why the evidence produced by meta-analyses may be more reliable than the results of some other means of amalgamating evidence without having to adhere to the unattainable ideal of procedural objectivity.

The reliability of meta-analyses' results depends not only on the way the analysts obey the rules, but also on contextual issues. First of all, the primary studies included in the analyses have to be soundly performed. Second, as RCTs may not be the best possible means of acquiring evidence on possible side-effects of drugs, outcomes of meta-analyses drawing from RCTs may not suffice to offer reliable knowledge on whether a given product should be used to treat a given ailment. The example on research on SSRIs highlighted the twofold relation between meta-analysis and the biases of original studies. On the one hand, publication bias impairs the reliability of meta-analyses' results by skewing the pool of available primary evidence. At the same time, however, meta-analyses and other systematic reviews (e.g., Bekelman et al., 2003) have demonstrated how published

and unpublished data differ. Together with qualitative reports (e.g., Sismondo, 2008a) these analyses help us identify problematic practices and find means of counteracting them. Since the social view recognizes that the level of evidence required for establishing different kinds of claims may be different, it allows us to hold on to the idea that meta-analyses produce valuable information on the effectiveness of treatments while, at the same time, acknowledging the limitations that the method has with respect to detecting possible side-effects. The social view directs our attention to evaluating research in its context, and thus adopting this view gives us tools for criticizing a system that disregards evidence produced by other means than RCTs and meta-analyses without abandoning the goal of objectivity. In this way, the social view "preserves" the objectivity of meta-analysis.

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Notes

1 Here the term reliability is not used in the sense of the discussions on the reliability of measuring instruments, i.e., the ability to produce consistent results.

2 Generally systematic reviews and meta-analyses are described in the following manner: A systematic review is a search for literature on a certain question by following explicit, predetermined criteria. A meta-analysis is a statistical technique for synthetizing information from systematic reviews. Cf. Rys et al. (2009).

3 The Cochrane collaboration is an international network that aims to provide reliable medical information for the needs of policy makers and medical practitioners by conducting and publishing systematic reviews.

4 As Douglas notes (2004: 462, n 12), Porter calls this ideal mechanical objectivity.

5 The link between the ideal of procedural objectivity and meta-analysis has previously been noted by Hammersley (2013: 100).

6 See Howick (2011) for a philosophical account of EBM.

7 See Goldenberg (2009) for a review of criticism of RCTs high evidential status.

8 For example, funnel analysis can be used to detect publication bias. However, this method as such does not help to answer the central question, i.e. whether the tested treatment is effective or not.

9 Later, the warning was updated to include young adults between 18 and 24 years of age (FDA, 2007).

10 In another article (Jukola, 2015) I discuss in more detail the way in which the source of funding can steer research towards certain kinds of explanations and, thus, bias research. There, I argue that the conditions for objectivity are partly dependent on the funding structure of science. See also Resnik (2007), Carrier (2010), Musschenga, van der Steen & Ho (2010), Sismondo & Doucet (2010).

11 Sismondo (2009) examines the work of publication planners and their relationship with other actors in medical science.

12 It should be noted that procedural objectivity does not secure value-freedom, either (see, e.g., Douglas, 2004: 462).
13 By 'generally acknowledged goals' I refer to goals that both researchers and non-scientists expect scientists to strive for. Some of these goals are shared by all research communities (e.g., empirical accuracy), some are community-specific (e.g., producing knowledge than can be used to develop practices for improving human health).
14 One could argue that following the procedural ideal does solve the problem of publication bias. After all, we could state that researchers should follow the rule of publishing all findings. However, it is likely that there will always be findings that, for a reason or another, are not worth publishing, and deciding which results should be made public requires judgment.
15 There have been more radical suggestions for tackling the roots of the bias in medical research via institutional changes: For instance, Brown (2010: 106); Carrier (2010: 164; 181) and Sismondo & Doucet (2010: 279) suggest changing the funding structure of the field.
16 The fact that both the studied effect and the context of application have to be clearly specified can doom generalizing the results of RCTs in social sciences (Cartwright & Hardie, 2012; Hammersley, 2013).

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Orit Halpern:
Beautiful Data: A History of Vision and Reason since 1945.
Durham & London: Duke University Press. 2015. 352 pages.

Orit Halpern embarks on an experimental and novel approach to the history of science and technology that is strikingly relevant to both present and possible futures of interactivity and digital media in contemporary society. *Beautiful Data* constructs a history of big data through the co-constitution of vision and reason in the second half of the twentieth century. It begins with the history of postwar cybernetic science, from a captivatingly non-militaristic perspective, alongside histories of human sciences, urban planning and design to trace the ways in which humans have been trained to sense and analyze the world. She calls attention to the increasing power and value of the human imagination and visualization of data, as digital information increasingly bombards our cognitive environments and occupies the expanding virtual space we live in today.

From the intersection of modern utopian ideals with architecture imagined by Le Corbusier to massive private "smart-city" initiatives in South Korea, Halpern historicizes the cultural influence of cybernetics on design and urban planning after the Second World War. This change in attitude Halpern defines as "communicative objectivity," emerging from the integration of cybernetic science, engineering, pedagogy and the arts, and producing patterned ways of visualizing big data. The performative, affective and seemingly infinite possibilities characteristic of these systems is what makes data arguably "beautiful" for Halpern. She embraces "communicative objectivity" in her own unique approach by chronicling patterns in discourse and methodology to illuminate a history of interactivity.

The book is divided into four sections, each making its contribution to the reformulation of observation and knowledge; from mechanical objectivity and authoritative truth to hyper-individualized agents in techniques of calculation, measurement and administration. Disciplinary boundaries are crossed and dialogues are developed between fields rarely overlapping in historical inquiry. The opening section, *Archiving*, begins in the ubiquitous days of cybernetics, largely focusing on Norbert Wiener and his colleagues at MIT to trace the role of cybernetic theory in reformulating concepts of storage, time and process from earlier notions of memory, knowledge and perception. With the reconceptualization of the archive a new form of methodological truth emerged based on the strength and density of networks and capacity to circulate information and action.

In the following section, *Visualizing*, Halpern transforms notions of space into an interface comprised of channels of communicative exchange, detailing prominent figures in creating postwar American infrastructures, such as György Kepes, Kevin Lynch and Charles Eames. Cybernetic concepts transformed the everyday life and practices of vision and cognition for Americans through aesthetic

practice, business and education. This marked the reformulation of perception and emergence of data visualization with the interface as the central concern for design. The human observer became both isolated and interactively networked in society requiring specific modes of attention associated with their environment. The management of visualization and aesthetics resulted in a discourse and economy for managing systems in a variety of fields ranging from advertising to urban planning. Halpern marks the IBM installation of the "information machine" that could "think" as the boost of a new information economy. The interest of social sciences in systems of society resulted in new strategiec solutions to the post-industrial economy and developing infrastructures that repressed and redefined problems in society through acts of consumption.

The third section, *Rationalizing*, traces the development of the cognitive and social sciences following psychiatrist and cyberneticist Warren McCulloch, as well as political scientist Karl Deutsch. Halpern analyses the shifts in discourse of "psychosis" and the redefinition of consciousness based on reason to cognition grounded by rationality, which produced new models of sense, measure and calculation of perception. Rationality became algorithmically defined for all situations resulting in the rise of nascent models for visualizing data and society. Visualization emerged as a set of techniques to manage, calculate and act on quantifiable, observable and measurable populations in society. This drove computational approaches to intelligence, economy and governance. Halpern argues that economists remain focused on old definitions of consciousness and choice despite the observed shift toward cognition and rationality after the Second World War. She suggests that rationality be understood as a contested interface allowing the imagination and agency to return to a self-reflexive subject.

In response to the transformation of cognition and perception, governance and rationality, Halpern problematizes the valorization of beautiful data through politics and aesthetics. The final section, *Governing*, explores a radical reformulation of the tactics by which bodies, territories and networks are governed through measurement and attention. Halpern speculates on technological inevitability and organization of contemporary forms of war and terror—interrogating the ethical and political implications of making data beautiful and affective.

Beautiful Data is an ambitious and commendable history of the present. For Halpern, a history of big data and digital media does not give simple causal answers and must be non-deterministic in its approach. She uncovers a history of probabilities and potential outcomes that are contingent on the human practices and experiences of interactive digital media. Halpern calls attention to the danger of repetition without difference in the conditioned ways we have come to sense and analyze the invisible world.

Beautiful Data is a pleasant complement and historical succession to Emily Thompson's (2004) "*The Soundscape of Modernity*." Both Thompson and Halpern explore materialities of space and trained ways of human sense that come to form our world. Thompson elucidates the prewar cultural processes and construction of a mechanically objective modern sound constituted by relationships between listeners and their environment. This is a notable accompaniment to readers compelled by the way in which Halpern beautifully details shifting forms of vision, rationality and economy after WWII.

Halpern opens our eyes to the invisible infrastructures of big data with seemingly endless possibilities and unknown futures. Big data is performative and "smart"—attuned to the behaviours and actions of humans in a new technological environment. The fetishization of big data has reshaped ideals and practices of truth and memory, transforming knowledge into organizations of power and governmentality. Halpern encourages us to engage with these sociotechnical networks differently and challenge our image of the interface.

Beautiful Data is an innovative, informative and highly enjoyable read for those who often find themselves hovering between disciplinary fields, offering a reflective history of early cybernetics, art, design, psychology and political science. Halpern guides her readers gracefully through a history of interactivity between humans and machines, the archive and the interface. This is accompanied by several cultural explorations and images revealing fascinating patterns in observation and form. Halpern grounds her book in a balance between the history and theory of human sciences as a point of departure for future projects and new ways of thinking about digital media, vision and cognition. The book is particularly useful in conceptualizing the cultural significance of cybernetics beyond its plural meaning in contemporary society. The pervasive nature of cybernetics prompts the opportunity for similar stories to be told based on historical probabilities and contingencies. *Beautiful Data* is an important read for those interested in the sociocultural influences of cybernetics, ubiquitous computing and big data in contemporary society.

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Stephen Graham & Colin McFarlane (eds)
Infrastructural Lives: Urban Infrastructure in Context.
London & New York: Routledge. 2015. xiii + 247 pages.

I read the opening lines of this book's foreword – written by the esteemed anthropologist Arjun Appadurai (2015), a widely recognized voice in globalization studies – with utter disbelief. "This timely book," Appadurai (2015: xii) writes, "is sure to become a definitive work on the now growing literature on urban infrastructure". The book is "timely," no doubt, but "sure to become a definitive work?" How outrageously bold!? This is the equivalent of unambiguously claiming that a modest edited volume such as *The Social Construction of Technological Systems* (Bijker et al., 1987) would become canonical in a small field such as science and technology studies (STS) after reading a pre-publication draft manuscript of the edited volume. Still, after reading *Infrastructural Lives*, I now agree with Appadurai (2015); his claim is not an overstatement. The volume has promise; it may live up to the hype. Still, the collection has a disconcerting blind spot.

The entire edited volume hangs on the following hook, which emphasizes *visibility* and *experience*:

> The analytical lens that gives this volume its originality is to make infrastructure more visible by tackling it not as a dimension of urban technology but as a dimension of urban everyday life (Appadurai, 2015: xiii).

This visible/invisible interface, which is culturally produced and differs from context to context, is of considerable utility to chapter authors. Of course infrastructure is intentionally hidden from plain sight, and for myriad reasons, often safety reasons. That infrastructure blends into everyday life (i.e., becomes taken-for-granted, and, thus, black-boxed) should be self-evident to sociologists and STSers who have, over the years, taken-for-granted such taken-for-grantedness. In this light, defending the significance of bringing infrastructure into the light for readers and making infrastructure visible through research hardly needs to be defended at all. The originality of emphasizing the notion of *visibility* is primarily in applying it to this new line of research aimed at uncovering how individuals around the world *experience* infrastructure or what the editors call "everyday infrastructural experience"[1] (Graham & McFarlan, 2015: 1). Thus, rather than focusing research efforts on determining some particular infrastructural system's capacity, it is inputs and outputs, or it is slow design and development over time, the editors aim to attend to – through a series of diverse case studies – infrastructure as a relational, material, and lived everyday experience.

The book offers readers fresh metaphors for conceptualizing infrastructure. Beyond the notion that infrastructure is experienced, infrastructure is framed in terms of "metabolic" processes (Graham & McFarlan, 2015: 6) wherein we learn that like humans, infrastructure needs "to rest, restore, and recuperate" (Shaw, 2015: 175),

or that the city is a "laboratory" (Cavalcanti, 2015: 89) that "metabolizes experiments" (Broto & Bulkeley, 2015: 202). There is incessant emphasis — at least the authors are all essentially on the same page — with an "ecology of practices" (Simone, 2015: 18).

This rather vague analytic frame of "ecology of practices" is associated with "improvisational urban practices" (Rao, 2015: 54), and impromptu negotiation of systematic failures in infrastructure referred to as "jugaad" (Rao, 2015: 54), and with the perpetual need for "incremental" practices (Simone, 2015: 32) associated with adjusting and readjusting infrastructure, all which are framed as "speculative anticipations" (Simone, 2015: 21). And there is more. That infrastructure seems to somehow feed off of its own discourse of "destruction, decay, and inadequacy" (Rao, 2015: 40) and "the politics of inadequacy" (Rao, 2015: 40) are fascinating themes in this edited volume, with important, but predictable, analysis of public discourse, especially in terms of the dispossession associated with the logic of "revanchinist" (Graham et al., 2015: 70) and "expansionist" (Salamanca, 2015: 117) rhetoric, which depicts the poor as a "pathology" (Graham et al., 2015: 70) and informal settlers as a sign of "social disorder" (Graham et al., 2015: 68; Cavalcanti, 2015: 88). In all, the edited volume hangs together effortlessly, and this is because of – not in spite of – the rich diversity of its chapters.

I would be remiss not to mention the title, which I both do and do not like. *Infrastructural Lives* could just as well have been *Infrastructure Lives*, to capture more fully the double entendre the editors imply. After all, a key insight is that at some times and in some places people *are* the infrastructure and, hence, we could say that this infrastructure *lives* (verb). Also, the primary research aim of the book is to capture the experience of living with infrastructure and, thus, we call these infrastructure *lives* (noun), as in, the lives of people coping with infrastructural environments.

In my closing remarks, I come full-circle, and reflect on *visibility* as a virtue, and the long-term dangers this poses as a justification for the conduct of research. The danger is that all this unveiling has a limited shelf life. "[W]hat gives this volume its originality," Appadurai (2015: xiii) writes, "is to make infrastructure more visible," which is a reasonable justification for undertaking this book-length edited volume. However, if the approach laid out in this book becomes the "definitive work" that Appadurai (2015: xii) so forcefully claims it will be, then, years down the line, the need for visibility may no longer serve as such a powerful justification for conducting research on urban infrastructure.

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Notes

1 Emphasis in original has been removed.

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