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Knowledge infrastructures: Part I

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The focus of this special issue is on Knowledge Infrastructures. We have witnessed important changes in research and knowledge production in recent decades associated with developments in information technologies and infrastructures. In some circles these changes are promoted as a transformative force enabling new forms of investigation, but they may also be perceived as buttressing existing forms of research. These developments aim to pull people together, supporting distributed collaboration or facilitating new joint activities and endeavors across domains, fields, institutions, and geographies. They potentially offer new opportunities for the sharing and connecting of information and resources–data, code, publications, computing power, laboratories, instruments, and major equipment. They often bring together a diversity of actors, organizations, and perspectives from, for instance, academia, industry, business, and general public. The social, material, technical, and political relations of research and knowledge production appear to be changing through digitalization of data, communication and collaboration, virtualization of research communities and networks, and infrastructuring of underlying systems, structures, and services. These emerging phenomena participate in ongoing transitions in the scholarly arena, and in society in general: traditional ways of doing research may be challenged and knowledge production may become more distributed and broader in participation. These phenomena have been cast under several labels such as big science, data-driven science, networked science, open science, Digital Humanities, and science 2.0. Other terms used are: e-Science, e-Social Science, e-Research, e-Infrastructure, and cyberinfrastructure.

The stimulus for this special issue was a common realization that the time has come to draw together the current state of developments in this topic area as viewed from the perspective of Science and Technology Studies (STS) and to evaluate the contribution of the distinctive set of theoretical resources of STS to the understanding of knowledge infrastructures. In doing so we build upon a considerable momentum of work in STS and related fields focused on the study of new infrastructures for knowledge production. The precursors of the current special issue include, for instance special issues in the *Journal of Computer-Mediated Communication* ('Exploring e-Science', Jankowski, 2007), *Journal of the Association for Information Systems* ('e-Infrastructure', Edwards et al., 2009; 'Innovation in Information Infrastructures', Monteiro et al., 2014), *Computer Supported Collaborative Work: The Journal of Collaborative Computing and Work Practices* ('Collaboration in e-Research', Jirotka et al., 2006; 'Sociotechnical Studies of Cyberinfrastructure and e-Research', Ribes & Lee, 2010) and the *Cultural Anthropology* journal ('The Infrastructure Toolbox', Appel et al., 2015).[1] Several workshops, conference sessions and theme-specific conferences have been held since. Edited collections on the topic include, among others, Hine (2006), Olson et al. (2008), Jankowski (2009), Dutton & Jeffreys (2010), Edwards et al. (2013), Wouters et al. (2013), and Mongili & Pellegrino (2014). Knowledge infrastructures have clearly piqued the interest of many scholars working in and around the STS tradition. The potential of knowledge infrastructures to unite a concern with the emergence of complex socio-technical systems with the enduring Sociology of Scientific Knowledge (SSK) interest in the micro-level practices and contingent outcomes of knowledge production makes them an attractive object for STS study. This interest is further stimulated by the emergence of knowledge infrastructures as a prominent topical field invested with significant cultural expectations, the focus of high profile investment from research funding bodies and government institutions.

Our aim in presenting this special issue on the topic of knowledge infrastructures is to take stock of existing research and chart new directions. For taking stock, the scope defined in the initial call for papers was deliberately inclusive. As an interdisciplinary research field, STS builds on a variety of disciplines and disciplinary subfields. Within the topic of knowledge infrastructures, several research perspectives are brought together. Interdisciplinary research integrations are often needed in order to engage with the complex technical, epistemological, and institutional aspects of these projects, and the cross-fertilization is broadening beyond the founding STS disciplinary field to include, for example, Social Informatics, Library Studies and Information Sciences. Also, while most of the existing work has focused on studying knowledge infrastructures in the natural, medical, and engineering sciences, studies of knowledge infrastructures in arts, social sciences, and humanities are on the rise, thus increasing the variety of domain-specific (sub) disciplines. In the call for papers we therefore did not restrict the domain of knowledge and, indeed, hoped to bring together papers that explored the development of infrastructures across a wide range of institutional settings and both within and beyond academic science. The resulting crop of papers has indeed realised this aspiration: in this issue we present papers relating to industrial environmental monitoring, public health surveillance, and Wikipedia's portrayal of schizophrenia. Future issues will expand the institutional focus again and also explore scientific and social scientific knowledge production. The juxtaposition will, we hope, enable an evaluation of cross-cutting themes and fruitful cross-fertilization of ideas across domains of knowledge that might otherwise be kept separate.

Taking stock and charting new directions in knowledge infrastructures research appears all the more necessary as the complexity of the phenomena calls for theoretical and methodological developments, actively engaging STS scholars to revisit existing approaches and contributions. The issues not only relate to how we can best study and understand knowledge infrastructures, but also how we could imagine them moving forward (Edwards et al., 2013) and to what extent we expect STS scholars to be an active part of imagining these futures.

In STS the study of infrastructures has roots in the history of Large Technical Systems: initially focusing on electricity supply networks (Hughes, 1983, 1989) subsequently exploring other large systems such as transportation, water supply, district heating, and waste management (Van der Vleuten, 2004). The seminal work of Star and Ruhleder (1994, 1996), studying an early infrastructure for scientific collaboration, provided a first conceptualization of infrastructure as a contextualized 'relation' rather than a 'thing' and emphasized the situated practical work of developing and using infrastructures. During the following two decades, the early studies and concepts became widely used to inform new infrastructure studies and developments in a variety of contexts (Edwards et al., 2007). Theoretical challenges for studying knowledge infrastructures include understanding of the complex multi-scale relations and multiple scopes involved, the local and situated dimension of infrastructure together with its global and pervasive nature, and the complex work of alignment and coordination of activities across different socio-material worlds and technological arrangements. These dimensions have been and continue to be the focus of many studies, providing interesting approaches, perspectives, and metaphors. Yet, important aspects and areas remain under-studied or under-understood. What are the main theoretical contributions of research on knowledge infrastructures in past decades? How could STS and other fields' perspectives, concepts and metaphors be revisited and advanced? Some tentative answers will be drawn out at the end of this editorial, but this key set of questions will be revisited in future issues as the corpus of papers builds.

Methodological challenges related to the study of knowledge infrastructures include their geographical distribution across multiple locations and within online spaces, their evolution over extended periods of time, their sociotechnical nature, the multiplicity and heterogeneity of participants and institutions involved as well as the 'double challenge' of having to understand both information technologies and the domain discipline(s) under investigation. Methodological developments so far have provided tools and orientations for studying the mundane and the invisible (Star, 1999), such as the 'infrastructural inversion' suggested by Bowker (1994) to focus on all the activities that warrant the functioning of infrastructure (e.g. formation, maintenance, upgrade, breakdown, repair) rather than those that it invisibly supports. New ways to study large or distributed phenomena – offline and online, as well as longitudinal, multi-sited, multi-scope, and 'messy' dimensions of infrastructures are suggested (Hine, 2000, 2008; Beaulieu, 2010; Karasti et al., 2010; Jackson & Buyuktur, 2014). As STS scholars have a history of 'intervening' while studying science and technology phenomena, approaches have been developed to not only analyse the outcomes of knowledge infrastructure work but also to engage actively with the formation, enactment, and co-construction of infrastructures (Neumann & Star, 1996; Ribes & Baker, 2007). As we issued the call for papers for this special issue, we were interested to examine what kinds of innovative methodological developments would emerge. How could existing methods be improved? What roles are STS scholars adopting in relation to the projects they study, and is an active or embedded STS emerging in this field? Again, this editorial introduction makes a first pass at identifying methodological approaches that prove promising, but this will be revisited in future issues.

Articles in this first part of the special issue

The three articles presented in this first part of the special issue provide some elements to frame our initial evaluation of emerging themes. We briefly review and reflect on the articles, whilst also pointing to the way they contribute to furthering our understanding of infrastructures for knowledge production. The following section then draws together emerging theoretical and methodological developments and evaluates their contribution to the existing literature.

The special issue opens with an article by Sally Wyatt, Anna Harris, and Susan E. Kelly focusing on a knowledge infrastructure that sits outside of scholarly knowledge production, narrowly defined. Wikipedia's infrastructure allows a diverse set of actors including scientists and lay people to participate in the production of a publicly available knowledge resource that aspires to be neutral and evidence-based. Wyatt et al.'s exploration of the processes that lead to the production of this knowledge resource suggests that rather than simply reflecting existing knowledge, the Wikipedia infrastructure offers a site of active knowledge production, through the work that goes into curation of resources, which in turn involves ongoing interpretation of Wikipedia's own rules for participation.

The article "Controversy goes online: schizophrenia genetics on Wikipedia" utilises a specific aspect of the Wikipedia infrastructure as a methodological tool. In order to explore the active practices underpinning the production of two key, and often controversial, Wikipedia entries focused on schizophrenia, the authors analyse the content of the Talk pages that track the editing of the page and record discussions between editors about appropriate edits to make. By focusing on the Talk pages relating to schizophrenia genetics Wyatt et al. are able to explore the interpretive work that lies behind decisions on what should be included in the page and on the weight to be given to the various positions within this highly controversial field of research. Editorial work is carried on with reference to over-arching rules for participation within Wikipedia, which require, for example, use of reliable published sources, prohibit original research, and dictate use of a neutral point-of-view. The Talk pages demonstrate a strong prioritisation of published scientific literature and also reliance upon published reviews to avoid having to curate lists of single studies and thus risking accusations of drawing original conclusions. However, the actual choice of points to include in the entries on schizophrenia is shaped in practice by a somewhat ad hoc interpretation of what counts as a credible study or an appropriate high-level review, by an embedded hierarchy among the editors and by differential expertise and access to resources across those editors.

Taken at first sight the infrastructure of Wikipedia, including the rules for participation, appears to act to discourage the emergence of controversy, but through the Talk pages Wikipedia preserves traces of the work through which this smoothing over of controversy is achieved. Wyatt et al. note that the production of the schizophrenia pages relies upon an active process of citation and curation that is at times contradictory and not always apparently in compliance with the overt rules of Wikipedia. Contrary to observations from previous STS studies of infrastructure that the work that sustains an infrastructure is often rendered invisible, the authors argue that Wikipedia provides an interesting case in which the infrastructure itself makes visible the work that goes into sustaining it. In particular, they suggest, Wikipedia and the internet more broadly offer STS a new array of sites to allow study of controversies in action.

The second article "A measure of 'environmental happiness': Infrastructuring environmental risk in offshore oil and gas operations" by Elena Parmiggiani and Eric Monteiro reports on the development of a knowledge production process and knowledge infrastructure to introduce environmental risk monitoring into an industrial setting. The oil and gas company in question wishes to establish a baseline for subsea environmental monitoring in response to the Norwegian government's promotion of knowledge-based approaches for decision-making affecting the environment. The company's selected site for performing real-time environmental monitoring is a sub-Arctic marine ecosystem off the coast of northern Norway. The area is estimated to be rich in petroleum resources but currently banned for drilling. Establishing a knowledge infrastructure for real-time environmental monitoring is seen to position the company favourably in the case of future opening of the High North for oil and gas operations. However, these inhospitable (to human) sub-sea areas are also ecologically rich in flora and fauna, providing habitats, for example, for the world's largest population of a species of cold-water coral and the world's largest stocks of fish, and the scenic coastline is attractive for tourism and recreation. Constant controversy prevails between environmental concerns, fishing industries and oil and gas operations.

Parmiggiani and Monteiro's article investigates the integration of a new type of activity, environmental monitoring, into the company's existing safety and risk assessment infrastructure as "an effort of innovation and experimentation at the fringes between operation-based monitoring and long-term environmental monitoring". The paper focuses on the data construction process across a knowledge-infrastructure-in-the-making with a specific interest in how uncertainty about the marine environment is quantified into a knowledge base. Three infrastructuring mechanisms are identified, i.e. sensoring, validating, and abstracting, to participate in the 'cooking' of the 'raw' data into a new "measure of environmental happiness". The little knowledge available of a small sub-marine location is quantified into representations of ecosystem behavior and embedded into the operations of a global oil and gas company. All this necessitates a knowledge infrastructure, the analysis of which needs to be able to account for the networked and long-term dynamic relations between social, technical, and natural elements.

Parmiggiani and Monteiro further our understanding of infrastructures for knowledge production by discussing how the emerging spatial, temporal, and socio-political tensions are leveraged in practice in the process of infrastructuring the sub-marine ecosystem into a baseline across the knowledge infrastructure. First, spatial tensions arise in the full range from data collection and interpretation to risk representations. A fishermen's echo sounder is repurposed for environmental monitoring, but as the sensor's location and (im)mobility as well as spatial perspective are altered, the 'same' data acquired with the 'same' instrument are rendered quite different for interpretation. Through risk representations, such as the coral risk matrix, environmental value indicators are made global but remain grounded in the historical data collected at the local site. Second, the real-time and long-term temporalities inherent to environmental monitoring pose new concerns. Environmental monitoring has become fast, interconnected, and open to close scrutiny. The different conceptions of time are frozen into different enactments of risk, such as the company's bonus/penalty contract and risk matrix, including understandings of compromises and trade-offs between the temporalities of risk to different participants (nature, partners, and oil and gas industry). Last, NorthOil, having a strong but contested political-economic position in the Norwegian context, has constructed its infrastructural activities in the sub-Arctic as a public problem for specific audiences. The infrastructuring mechanisms are complemented by continuous application of strategies, such as social networking and openness with regard to risk representations. These measures are directed at building trust (rather than consensus) because while the means of environmental monitoring can be shared the ends are seen differently by fishermen, research institutions, and the general public.

The final article of this first part of the special issue, by Angie M. Boyce, reports on public health surveillance activities in the US and the repurposing of materials and data in connecting heterogeneous infrastructures. Public health surveillance activities depend heavily on infrastructures built for other purposes to achieve their goals (they are 'second-order systems'); materials, data and information from the health care and food systems need to be connected to identify the ultimate cause of an outbreak. The paper presents an ethnographic analysis of a case of foodborne outbreak detection to analyze the practical work of repurposing materials and data from other sources and address the 'frictions' that arise between the systems and infrastructures.

The article "Outbreaks and the management of 'second-order friction'" addresses two important aspects of infrastructural interdependency: the practical work of creating and maintaining dependent systems and the broader sociopolitical and ethical consequences of interconnecting infrastructures. Public health surveillance implies piecing together and reworking materials and data created by diverse actors in different contexts. The role of the health care system is to treat patients, and in order to do so to collect information relevant to fulfilling its clinical function, while public health surveillance implies collecting, analyzing and interpreting health data in a systematic way, as well as integrating them into programs for prevention and control. The paper shows how connecting these heterogeneous sociotechnical infrastructures goes on through a daily work of 'repurposing' activities (for instance when a database managed by a national laboratory is being repurposed into a local laboratory-epidemiology communication tool). The paper also shows that collegiality matters immensely for smoothing the frictions arising in such critical contexts, in which important information is generated at different times by different players. If databases serve as key tools, the human dimension of infrastructure (Lee et al., 2006) is also of particular importance.

Boyce introduces analytic language for understanding *multi-infrastructural dynamics*, by making use of notions such as 'repurposing' and 'friction' to surface the 'invisible work' (Star, 1999) of making infrastructures built for other purposes to serve public health needs. If these notions have proved to be helpful tools to study understudied dimensions such as infrastructure maintenance and repair (Jackson, 2014), her study shows in great details how they also help in understanding the nature of the dependent relationship between 'first-order' and 'second-order' infrastructures, together with the challenges entailed. The notion of 'second-order frictions' is suggested to talk about how the actors "enact and experience" the dynamic relationships between the different infrastructures involved in repurposing activities. They encounter frictions of many forms, such as 'moral' frictions associated with using shopper card data to assist in outbreak investigations (as a mean to address limitations of 'food histories' data collected through interviews with affected individuals), or concerns over data interoperability (when culture-independent rapid tests are preferred over culture-based methods in the health care system). The interconnection of multiple and heterogeneous infrastructures often implies broader sociopolitical and ethical consequences, and public health surveillance infrastructures provide good illustrations in this respect. Public health surveillance infrastructures become visible only when an outbreak occurs–connections between the public health and the food systems are made only in the context of outbreaks, on an ad-hoc basis. The invisibility of these infrastructures may definitively contribute to their neglect and potentially thus influence the health of the population.

Reflections on emerging knowledge infrastructure themes

The three articles presented in this special issue investigate knowledge infrastructures as diverse as Wikipedia, an environmental monitoring system in industrial settings, and public health surveillance infrastructures. They all present new ways of creating, generating, sharing, and disputing knowledge and explore the altered mechanics of knowledge production and circulation. The studies contribute to our understanding of infrastructures for knowledge production in different ways, each of them shedding new light on certain dimensions of knowledge and of infrastructure and contributing new threads to the STS interest in this field. In this section we draw out a preliminary set of cross-cutting theoretical themes and significant methodological issues.

With the notion of infrastructure comes the crucial question of scale: an issue rendered even more complex in this field as by their nature knowledge infrastructures are often accrued/layered and dispersed rather than discrete identifiable objects (both to those studying them and to those involved in their development and use). Knowledge infrastructures are seldom built *de novo* (Star & Ruhleder, 1994, 1996), they gather and accrete incrementally and slowly, over time (Anand, 2015). They are brought into being on top of existing infrastructures that both constrain and enable their form (Star, 1999). Knowledge infrastructures are ecologies consisting of numerous systems, each with unique origins and goals, which are made to interoperate by means of standards, socket layers, social practices, norms, and individual behaviors that smooth out the connections among them. The adaptive process is continuous, as elements change and new ones are introduced–but it is not necessarily always successful (Edwards et al., 2013: 5). While knowledge infrastructures may connect and coincide, they seldom fully cohere (Anand, 2015). Given the accrued/layered nature of infrastructure, navigating among different scales–whether of time and space, of human collectives, or of data–represents a critical challenge for both the design, use and maintenance of knowledge infrastructures (Edwards et al., 2013: 8) as well as for their investigation. The knowledge infrastructures under study in the three papers here are large-scale infrastructures. They share typical infrastructural qualities, e.g. involving numerous entities, reaching beyond one-site practice, and implicating copious stakeholders. They span multiple information environments, technologies, organizations, regulatory frameworks, and so on. It is important, then, to note how the researchers have carved out the knowledge infrastructure for their investigation as this entails decisions as to which aspects of the infrastructure are included and which parts are ignored. It is important to recognize that "infrastructures operate on differing levels simultaneously, generating multiple forms of address and that any particular set of intellectual questions will have to select which of these levels to examine" (Larkin, 2013: 330). Study of knowledge infrastructures is often a process of identifying possible connections and potentially relevant contextualizing factors in tentative fashion, pursuing those connections that enable particular practices and decisions to make sense. The three papers presented here exemplify a careful approach to the emergent boundaries of the study but ultimately make contingent and potentially consequential choices on the specific focus of attention, shaped partly by the agency of the field in rendering some connections more possible to follow up than others.

Invisibility is a fundamental notion in infrastructure studies (Star & Ruhleder, 1996; Neumann & Star, 1996; Star, 1999, 2002; Bowker & Star, 1999; Bowker et al., 2010). The issue of invisibility resonates through the articles as an important analytical key to understand knowledge infrastructures. In this context, invisibility may refer to the invisible nature of the infrastructures themselves (Star & Ruhleder, 1996), the invisible work performed by actors (Shapin, 1989), and the processes of making visible–or invisible–activities and related challenges (Bowker et al., 1995). If the latter two have been much to the fore in studies on infrastructures, the invisible nature of infrastructures themselves has rarely been put into question. Indeed, we often consider infrastructures as invisible entities almost by definition, disappearing into the background along with the work and the workers that create or maintain them. Thus, infrastructures are often analysed in the making, in case of breakdown (Bowker et al., 2010) or observed as they are being formed, used, maintained, or repaired (Star & Bowker, 2002; Karasti et al., 2010; Jackson, 2014) since these moments make visible parts and aspects otherwise hard to uncover.

While invisibility is thus a recurrent theme in STS-influenced studies of infrastructure, experience has shown that some knowledge infrastructures are more amenable than others to study and that they do not all share the same degree of invisibility. This differentiation is seen across the three articles presented here. In Parmiggiani and Monteiro's study, the researchers realised that the workers involved in developing the new environmental monitoring knowledge infrastructure for the company, in fact, sought to answer the same questions as the researchers; they were engaged in making visible many hidden infrastructural issues, both existing and new, relating for instance to data, the sub-sea environment, and the instruments. The public health surveillance infrastructures studied by Boyce, in turn, may be envisioned as typical invisible infrastructures; they take shape at specific moments in time (in case of an outbreak) and even then, they do not present themselves as well delimited and easy to grasp entities but rather as complex and messy assemblage of systems, organisations, and people. An infrastructure like Wikipedia as studied by Wyatt et al. provides a set of online spaces that enable the practices behind curation work to become visible (the 'talk pages'), thus allowing the observation of the controversies in action. In this particular case, it is a specific property of the Wikipedia infrastructure that becomes a methodological tool for studying some otherwise less visible activities of knowledge production. Looking across these three cases, then, the classic concern of STS infrastructure studies with invisibility appears, but this invisibility plays quite different roles in the narrative of the articles and in the trajectory of the projects they study. In studying new infrastructures for knowledge production in quite different fields of deployment it is clear that we need to be sensitive to the varying orientations of the actors involved and those studying their work to the various degrees of silence and openness that this work entails.

The three articles share an STS perspective that does not expect sociotechnical work to proceed smoothly and is not only interested in the ultimate 'winners' but pays careful attention to the emergence of tensions, frictions, and controversies when studying these infrastructures and understands that the particular sets of relations that emerge through the development of an infrastructure could always have been otherwise. Where the infrastructure in question is a repository of knowledge, the way in which these tensions, frictions and controversies are identified (or ignored) and handled by participants is potentially highly consequential in shaping the resulting knowledge. The papers presented here exemplify the STS-inflected concern with questioning how a knowledge infrastructure emerges, who contributes to its fabrication, how it is made sustainable, and what are the wider political challenges associated with its development.

Because knowledge infrastructures always embody some kind of political agenda, because they 'grow' on a pre-existing installed base–'piggybacking' on other infrastructures–they pose multiple sources of friction, conflict, or resistance activities. Aligned with the issues of tensions, frictions, and controversies, the articles presented here identify and discuss infrastructural activities that also speak to the dynamic, evolving nature of the knowledge infrastructure: enacting; infrastructuring through diverse forms of work including technology development, data generation, processing, and circulation, building trust with participants and potential users, and operating effectively on the socio-political level; and repurposing. Inherent in much of this work is the management of ambiguity and uncertainty and the development of specific relations of accountability to decide who makes determinations of whether a particular knowledge infrastructure or dataset is "good enough" for purpose. Of particular importance for the study of the knowledge infrastructures presented here are the processes by which pieces of knowledge are produced, circulated, repurposed, boxed, contested, or validated. This may imply looking at, among other things, how 'raw' data become 'cooked' to produce information, how a standard is enacted, in what ways a system gets repurposed, or how new representations are constructed to quantify risks for the environment.

If scale, invisibility, tensions, uncertainty, and accountability are among the interesting features of knowledge infrastructures, then how does this imply that we should study knowledge infrastructures? While infrastructures are often conceived of as large-scale entities, a common entry point for studying them is a level of analysis at a smaller scale. The methods used in two of the three articles (Boyce; Parmiggiani & Monteiro) are ethnographically inspired, whereas Wyatt et al. employ thematic analysis on the corpus of data collected from Wikipedia. Wyatt et al. neatly bound their empirical research object by collating all material related to two English-language schizophrenia genetics Wikipedia articles. They analyse the citation and curation of ambiguous scientific knowledge by examining 'infrastructural details' of internet technology, i.e. text, images, hyperlinks, and 'talk pages' that make visible the social actions of negotiating, producing, and circulating new forms of knowledge that is potentially global in its distribution.

The two ethnographically inspired articles engage in the 'infrastructural inversion', that allows researchers to scrutinize infrastructural "technologies and arrangements that, by design and habit, tend to fade into the woodwork" (Bowker & Star, 1999: 34). Their operationalisations of infrastructural inversion are, however, quite different. Boyce tacked "back and forth between the practical work of maintaining second-order systems, and the socio-political and ethical consequences of that work as a form of 'infrastructural inversion'" in order to better appreciate the "depths of interdependence of technical networks and standards on the one hand and the real work of politics and knowledge production on the other" (Bowker & Star, 1999: 34). She looked at the 'frictions' created by the interconnection of disparate infrastructures, finding that these frictions take many forms and are of different orders, ranging from technical incompatibility to moral concerns (e.g. repurposing shopper card information into data for food outbreak investigation). Parmiggiani and Monteiro, after realizing that the company employees were engaged in activities of infrastructural inversion as part of their work of developing the environmental monitoring knowledge infrastructure, followed the key actors in the field in order to learn with them. Based on this they were able to bring to the forefront also wider socio-political issues associated with knowledge infrastructures, focusing on, for instance, the ways in which a 'private' infrastructure of an enterprise became constructed as a public concern. In both of these studies the operation of infrastructures at multiple levels simultaneously, as outlined by Larkin (2013), becomes a live issue for the researcher to handle as they decide which aspects to examine and how, practically speaking, to bound their object of analysis.

Ensuing parts of the special issue

The initial call for papers on knowledge infrastructures received a good response, and has produced more papers than will fit in a single issue of the journal. Thus, the special issue will consist of several parts that will all appear in the course of year 2016 as papers complete the review process. In the special issue call for papers we solicited studies of knowledge infrastructures not limited to scholarly knowledge production, but addressing also, for instance citizen/civil science, as well as studies that address emerging forms of knowledge production, such as open data/science, or studies that explore knowledge infrastructures in commercial or public services domains. This request was generously responded to, as the articles in this first part of the special issue testify. The following parts will continue portraying the diversity of knowledge infrastructures both within and outside the academy, featuring also some more geographical breadth by including articles also from researchers outside Europe and the US. In future editorial introductions we will develop the analysis of emergent theoretical and methodological themes, in particular discussing further significant knowledge infrastructure themes, such as temporality and accountability, as they arise in the articles. In the editorial for the last part of the special issue we will focus particularly on charting new directions for the study of knowledge infrastructures.

Notes

1 Closely related to the topic and concept of infrastructure, mainly concerned with social studies of energy, two recent sets of special issues of the *Science & Technology Studies* journal have also developed similar themes, see Silvast et al. (2013) and Williams et al. (2014).

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Controversy goes online:
Schizophrenia genetics on *Wikipedia*

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Abstract

Scientific controversy is increasingly played out via the internet, a technology that is simultaneously content, medium and research infrastructure. Here we analyse material from *Wikipedia*, focusing on schizophrenia genetics. We find that citation and curation of scientific resources follow a negotiated, ad hoc adherence to *Wikipedia* rules, are based on limited access to scientific literature, and thus lead to a partially constructed 'review' of the science that excludes non-professionals. Given its policies and systems for developing neutral, evidence-based articles, one would not expect to find controversy on *Wikipedia*, yet we find traces. Scientific ambiguity about schizophrenia genetics lends itself to multiple ways of curating resources, and the infrastructure of online spaces enables the practices behind curation work to become visible in new ways. We argue that not only does *Wikipedia* make scientific controversy visible to a wider range of people, it is also involved in the production of knowledge.

Keywords: controversy; research infrastructure; *Wikipedia*

Introduction

Controversies have long been of interest to social scientists engaged with the social, cultural, moral and political aspects of medicine, science and technology. Controversies are considered interesting because they offer insight into the processes by which facts become stable, before science becomes 'normal' (Latour, 1987). Decades of scholarship, particularly in science and technology studies (STS), have empirically shown that a vast array of actors are involved in controversies. Sometimes these are between scientific peers (Collins, 1975, 2004; Shapin & Schaffer, 1985; MacKenzie, 1990) but controversies can also involve others, such as patients and their advocates (Epstein, 2008), sheep farmers (Wynne, 1992), and bee keepers (Suryanarayanan & Kleinman, 2013). In these (and other) accounts, actors draw on various forms of experience and expertise to position themselves within their particular area of contestation, shaping how the controversies unfold and what becomes established as fact.

Technological infrastructures of communication also play a role in how controversies take shape.[1] Historical examples can be found in the information infrastructure of postal systems in the 17th and 18th centuries, enabling the exchange of public and private correspondence between scientific 'men of letters' (Bowker et al., 2010: 104) or the mass circulation of peer-reviewed journals in the mid-19th century (Lightman, 2011). As the distribution patterns of scientific knowledge exchange widened with the development of these communication technologies, alongside developments in transportation, communication within the scientific community became, as Bowker and colleagues (2010: 104) write, 'no longer two-way, but n-way', implying a multiplicity of possible directions, a move that would be strengthened by open access to scientific publications.

We start from the assumption that new technologies of communication support forms of knowledge exchange while also creating new sites for scientific controversy. In particular, we examine how the internet provides an infrastructure for the representation and production of scientific knowledge (Bowker et al., 2010; Niederer & van Dijck, 2010; Wouters et al., 2013). The 'internet' is far from monolithic, comprising a multitude of pages, links, media and platforms, each with their own meanings, practices and possibilities. We focus on a specific scientific topic, schizophrenia genetics, and how it is discussed on a particular platform, namely *Wikipedia*. As we discuss later, schizophrenia genetics research itself is a particularly controversial area of medical science that has already captured the attention of STS scholars (Hedgecoe, 2001; Rabeharisoa & Bourret, 2009; Arribas-Allyon & Bartlett, 2010). Recent directions in schizophrenia research call for 'polyevidence' studies or mega-analyses (e.g. Schizophrenia Psychiatric Genome-Wide Association Study [GWAS] Consortium, 2011), which draw together singular studies and meta-analyses, pulling into alignment evidence from research conducted using similar or different methodologies, some including cross-species databases.

While social scientists have examined various contexts in which scientific knowledge is played out, few have focused specifically on the ways in which scientific knowledge is represented and produced online. There has been a recent focus in STS on the role of the internet in database management and knowledge production (Bowker, 2000; Hine, 2006; Leonelli, 2012). Such work examines data-based exchanges between scientists and others involved in scientific work. We complement this by looking at exchanges occurring outside the 'core-set' (Collins & Evans, 2002) of schizophrenia genetic science, namely by examining *Wikipedia*, a public internet platform accessed and constructed by users with a wide range of both professional and experiential expertise. As a prominent, almost paradigm exemplar of user-generated content, *Wikipedia* offers useful insights into the ways in which web material is constructed from scientific resources by a range of actors with diverse sets of expertise.

Spaces of contestation, controversy and debate regarding psychiatric illness have largely been restricted to physical locations such as clinical meeting rooms (Spandler, 2009), classification manuals (George et al., 2011; Kawa & Giordano, 2012), and in the field of schizophrenia genetics more specifically, the clinic, the clinic-laboratory interface (Rabeharisoa & Bourret, 2009) and journal publications (Arribas-Allyon & Bartlett, 2010; Hedgecoe, 2001). Researchers have queried whether the internet will allow room for new forms of 'psychiatric contention' to develop (Spandler, 2009: 678), and we address this by looking at what happens when knowledge about schizophrenia genetics is produced for *Wikipedia*.

We focus on how the technical architecture of *Wikipedia* shapes the utilisation of knowledge resources, rather than on the content of the research studies. In this way our work is distinguished from that of other researchers who, in the context of psychiatric genetics, have examined how scientific resources are taken up in the clinic (Rabeharisoa & Bourret, 2009), or cited in review articles (Hedgecoe, 2006). We focus on the schizophrenia entry in *Wikipedia*.

We suggest that *Wikipedia* exhibits a particular kind of 'curatorial work', a term we use to describe the management of information. The word 'curator' is derived from the Latin word that means 'to take care of', and is applied to guardianship roles as varied as priests, spiritual leaders and royal functionaries (Cash Cash, 2001: 139; quoted in Kreps, 2003: 315). In the late 19th century, the position of curator was established in museums, as they expanded their collections and professionalised their operations. At that time, curators were considered 'keepers of collections' and the term curator continues to be most associated with museum work, although it is increasingly being applied in many other contexts. Over time the work of a curator in a museum broadened beyond caring for, managing and preserving collections, to researching, interpreting and presenting collections to a range of different audiences (Kreps, 2003). One prominent role for museum curators has been the selection of works from their collections for exhibition (Harris, 2010). But, as Harris (2010) points out, the public are increasingly taking on curatorial tasks in a 'participatory' move in museums, as visitors become involved in the selection of works for display, questioning traditional roles of curatorial authority and expertise.

Leonelli (2012) also uses the notion of curation in her analysis of cross-species databases. She identifies four technical problems arising from the epistemic differences between those contributing to the databases, including '(1) what counts as reliable evidence, (2) the selection of meta-data, (3) the standardization and description of research materials, and (4) the choice of nomenclature for classifying data' (Leonelli, 2012: 216–217). The first of these is most relevant for us, and we also use the notion of curation, derived from museum studies, to discuss how resources are selected and rendered credible, by a broadening set of actors. In *Wikipedia*, we observe conflicts about authority, and particularly about what counts as reliable evidence.

In the next section we locate our approach within STS studies of the internet and healthcare, and explain how we selected and analysed the empirical material on which this article is based. We then provide an explanation of the complex and controversial area of schizophrenia genetics in order to help the reader to understand the subsequent analysis of the material we found on *Wikipedia*. In the final section, we reflect on what our analysis means for future studies of controversy and a research infrastructure such as the internet. Central to our analysis is the recognition that platforms, infrastructures and infrastructural relations (Star & Ruhleder, 1996) are not neutral, and that they sometimes serve to reinforce established social positions, even if not always intending to do so. Unlike Star and Ruhleder (1996), however, we suggest that the social and technical relationships underlying *Wikipedia* are not always invisible, and that its workings are visible not only to STS researchers but also to those who engage with *Wikipedia* in whatever capacity.

Science, medicine and the internet

Since its inception in the early 1970s (the exact date is itself subject to dispute), the internet has been embedded in many kinds of scientific endeavour. It continues to play an important role in scientific research practice, including the ways in which research groups collaborate, the sharing and analysis of large quantities of data, the dissemination of findings, and the social division of research labour (Thomas & Wyatt, 1999; Abbate, 2000; Agar, 2006; Hine, 2006; Leonelli, 2012). The internet has affected the nature of scientific questions asked, the interdisciplinary nature of scientific teams, the data sets used and shared, the relationship between those who create and generate data and those who use them, the types of expertise relevant to knowledge production, and the distance between researchers and participants. The internet also changes the temporal dimensions of research, with pressure upon scientists to conduct and publish quickly, for media to report findings speedily and for industry to respond to emerging markets (Nowotny et al., 2001; Pels, 2003).

The role of the internet in healthcare practice is also becoming increasingly visible (Adams, 2010; Wyatt et al., 2008). So-called 'web-2.0' platforms such as blogs, fora and social networking sites are transforming relationships between health-care professionals, patients, consumers, funding agencies, healthcare systems and industry (Dedding et al., 2011). Notions of 'the clinic' have expanded so that therapy sessions by psychologists, social workers, psychiatrists and genetic counsellors now more frequently occur via the internet (Christensen & Hickie, 2010; Harris et al., 2013; Meropol et al., 2011; Mort et al., 2003; Oudshoorn, 2012) using technologies such as webcams (Pols, 2011). Patient and user group internet fora demonstrate that the internet can be a space to share experiences and resources, discuss research developments and act as a platform for (mediated) exchange between users, for example through Listservs or bulletin boards (Kaplan et al., 2011; Prainsack, 2013). Patient-experience websites such as *HealthTalkOnline* and *PatientsLikeMe* (Tempini, 2015) demonstrate other ways in which patients, carers and others, can engage with each other, and potentially conduct their own research (Allison, 2009). The internet has a role to play in many (mental) health-related practices from making local support groups more visible, to providing contact details for hospitals and clinics and other informational sites. Ensuring quality of health information online has long been a concern (Adams & Bal, 2009), and this issue also emerges in relation to the health pages of *Wikipedia*.

All of these various forms of internet-mediated healthcare raise issues concerning privacy, expertise, rapport, access, exclusion and anxiety. Often celebrated as a tool of empowerment (Jenkins, 2006; Surowiecki, 2004; Tapscott & Williams, 2006), particularly in the scientific and medical fields, others have shown that engagement with web technologies is more complex, involving the replication of dominant hierarchies, differences in access and new kinds of 'free labour' (Goldberg, 2011; Proulx et al., 2011; Terranova, 2000). Our analysis builds upon these critical studies of the internet, which recognise the contradictory aspects of web engagement, where internet infrastructure both enables and constrains engagement with scientific research. The example of schizophrenia genetics provides insight into the role that *Wikipedia* plays in the production of knowledge about a particular medical condition, that is itself controversial, both in its definition and in the understanding of its causes.

Methodology

Our analysis focuses on how research into the genetic basis for schizophrenia is presented and contested in *Wikipedia*. We began collecting *Wikipedia* data in October 2011 by collating all material related to schizophrenia genetics.

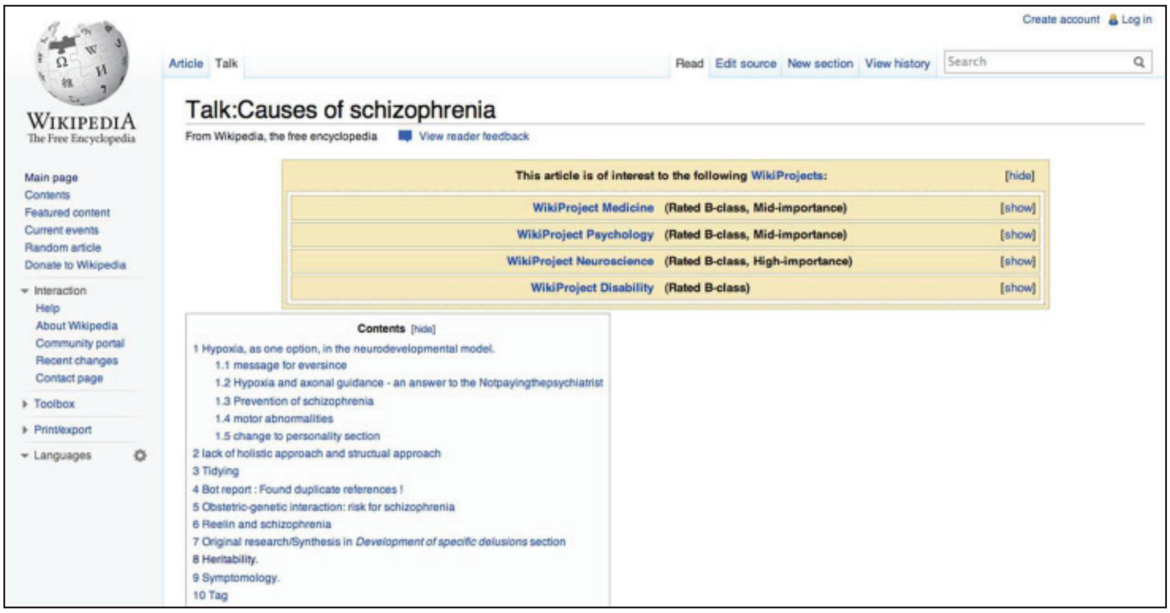

Figure 1: 'Causes of Schizophrenia' Talk pages, accessed 10 October 2011

Relevant material was sourced from the English-language 'Schizophrenia' article and from its 'daughter' article, 'Causes of schizophrenia' (see Figure 1). All material on these pages was read systematically for relevance to schizophrenia genetics. We looked not only at text and images in the articles but also at the 'talk pages' for these topics, which are archived conversations between editors accessed via the background tab on most *Wikipedia* articles.

In the 'talk pages' users are encouraged to articulate the reasons for their edits, and bot edits (automated edits made by software) are also made visible. The talk pages are sites for exchange of controversial views as editors justify their actions, and participants negotiate whose expertise is trusted and which resources are to be used. The talk pages thus offer rich material for social scientists wanting to study how the representation of controversial scientific knowledge is discussed, debated and revised by internet users. Given the multiple purposes of these talk pages however, much of the material was irrelevant to our study, such as discussions about duplicated references and tagging, or other biological causes of schizophrenia. In order to identify relevant sections, the complete material was screened a second time to find entries related to genetics. The *Wikipedia* material we collected dated from August 2006 to October 2011, and included 20,000 words of talk text and 13,000 words of article text.[2] This material is available for consultation with the authors.

Our methodological approach to the internet aligns with those who consider the infrastructural details of internet technology as important and worthy of analysis (Beaulieu & Simakova, 2006; Bowker et al., 2010; Hine, 2006; Wouters et al., 2013). For this reason we examined infrastructural details such as hyperlinks, which provide insight into how online spaces share and circulate scientific resources (Beaulieu, 2005), as well as examining where decisions concerning the controversy are made more visible, such as in *Wikipedia* talk pages (König, 2013).

We performed thematic analysis of all collected material including words, images and hyperlinks. Analysis involved detailed and repeated readings of the material, looking for themes (Lupton, 1997). When examining this material, we focused on how scientific resources were utilised. For example, we examined text on the *Wikipedia* talk pages where editors negotiated the inclusion of resources.[3]

Schizophrenia genetics

Schizophrenia is a mental illness characterised by severe psychosis, with clinical symptoms of hallucinations, delusions and interference with thought processes. The disorder is chronic and can be marked by apathy and social isolation. Schizophrenia has a prevalence of 1% in the general population. Since the early 20th century, when schizophrenia was first labelled, a familial aspect has been suspected. While schizophrenia is known to be highly heritable, with an estimate between 80% and 90%, scientists have struggled to reach consensus about the genetic basis for the condition (Lewontin, 1991; Hedgecoe, 2001).

As technologies of genetic analysis have evolved, the methods of searching for genetic associations with schizophrenia have changed from the early focus on twin and adoption studies. More prevalent in the early 21st century are reports of genome-wide association studies (GWAS) which can detect genes with small effects by scanning the whole genome in large study populations; the results of research studying gene and environment interactions; and rare and de novo mutations (Burmeister et al., 2008; Maiti et al., 2011; Tienari et al., 2004; Walsh et al., 2008). In a move from 'meta-analysis' (see Jukola, 2015) to 'mega-analysis', research is being conducted by well-funded large consortia which amalgamate databases across multiple research institutions in the hope of finding rare genetic associations for schizophrenia. A study from The Schizophrenia Psychiatric Genome-Wide Association Study Consortium (2011) combined GWAS data from 17 separate studies conducted in 11 countries, involving almost 10,000 cases and over 12,000 controls. A study published in *Molecular Psychiatry* in 2012 brought together data from these GWAS, as well as results concerning linkages, copy number variants, gene expression (from human post-mortem samples, cell lines, or blood samples), and animal model studies of schizophrenia (GenomeWeb staff reporter, 2012).

Controversies have plagued this continually evolving field, including its association with eugenics, the role of twin and adoption studies in understanding the genetic basis of the mental illnesses (Hedgecoe, 2001), and the failure of genetic linkage studies to find 'genes for' schizophrenia (Arribas-Allyon & Bartlett, 2010). Despite a series of 'landmark' research papers mentioned above, there remains no consensus on identifying an exact genetic cause of schizophrenia (Duncan & Keller, 2011). Concern is raised in academic journals, in newspapers, and in blogs, about the lack of replication of research findings and whether each new study ever reveals anything really novel. Some believe that the difficulties lie in an unclear definition of the schizophrenia phenotype (Frazzetto, 2009), which is based on clinical examination and diagnostic criteria in the *Diagnostic and Statistical Manual of Mental Disorders* or the *International Classification of Disorders* (Burmeister et al., 2008: 529). These diagnostic criteria are themselves controversial, in the clinic and in research (Hedgecoe, 2001).[4] Considering this diagnostic uncertainty, some researchers advocate for research into endophenotypes, a somewhat vague concept used in psychiatric genetics from the 1970s to mean a heritable trait or characteristic of a condition, such as anxiety, that recognises that genetic variants do not map neatly onto current diagnostic categories (Insel & Wang, 2010). Endophenotype research, adopted by one of the DTC GT companies discussed below, is argued however to be just another framework for the same project of attempting to understand the genetic basis of schizophrenia (Arribas-Allyon & Bartlett, 2010).

Schizophrenia genetics remains a controversial area of research (Brzustowicz & Freedman, 2011; Burmeister et al., 2008; Mitchell et al., 2010). Following all of the controversies in this scientific field is beyond the scope of this article, however it is important to locate our argument within this contentious area of scientific research related to schizophrenia genetics as well as within the controversial nature of internet-mediated healthcare and scientific practice, as outlined above.

Wikipedia: Talk below the surface

> The causes of schizophrenia have been the subject of much debate, with various factors proposed and discounted or modified […] Some scientists criticize the methodology of the twin studies, and have argued that the genetic basis of schizophrenia is still largely unknown or open to different interpretations [hyperlink to resource] (Causes of schizophrenia article, *Wikipedia*, accessed 10 October 2011).

So begins the *Wikipedia* 'Causes of schizophrenia' article, a daughter article of the 'Schizophrenia' page, sub-divided in order to cope with the sheer volume of information on the aetiology of the disease. This quote explicitly recognises the contested nature of scientific research in the area. How are such statements constructed, or in other words, what is the work which goes into making these claims? What resources are used as evidence? In this section, we address these questions, focusing on how the technologies and norms of *Wikipedia* shape and produce scientific knowledge.

Building a wiki

Wikipedia began in 2001 under the name of *Nupedia*. At that time, academic experts were invited to write articles in an encyclopaedic format. This approach was abandoned due to the slowness of editing. A wiki format was then adopted where scholars and interested lay people could contribute content (Niederer & van Dijck, 2010; König, 2013). While the early wiki adopters were mainly an elite group, from 2006 the number of novice users steadily increased (Niederer & van Dijck, 2010), forming a larger *Wikipedia* 'community' (Pentzold, 2011).

Wikipedia has received significant criticism regarding the contested ability of anonymous amateurs to produce accurate information. Nonetheless a study by *Nature* found that it was not significantly any more inaccurate than the *Encyclopædia Britannica* (Giles, 2005), even though the range of topics covered varies dramatically.[5] Britannica responded by challenging the methods used in the *Nature* study, whereas *Wikipedia* responded by correcting the mistakes.[6] In any event, *Wikipedia* pages are some of the most commonly visited on the internet. Scholars have both celebrated its democratic potential (e.g. Surowiecki, 2004) and critiqued it for retaining hierarchies and reinforcing dominant viewpoints (König, 2013). Niederer and van Dijck (2010) suggest that many discussions of *Wikipedia* have been misguided in that they focus on human resources, neglecting the technological tools and managerial dynamics that structure and maintain content. We follow Niederer and van Dijck (2010) by focusing on how the infrastructural arrangements of *Wikipedia* not only shape the representation of scientific knowledge, particularly evident in the talk pages, but also contribute to the production of knowledge.

Rules for participation

Some of the most important infrastructural arrangements shaping *Wikipedia* content are the rules for participation, upon which editing decisions are based. The existence of these rules would, at first glance, rule out the appearance of controversy on the pages of *Wikipedia*. The NOR (No Original Research) rule states that all material must be attributable to a reliable, published source. The NPOV (Neutral Point of View) rule states that representation needs to be given proportionally, without bias, of published information by reliable resources. A related sub-rule is SYNTH (Synthesis of published material that advances a position) that disallows the combination of material from multiple sources to reach or imply a conclusion not explicitly stated in those sources. If one 'reliable source' says A and another 'reliable source' says B, these cannot be joined to make conclusion C, as that would be considered to be original research (see NOR rule above). Contributors who deviate from these rules have their edits blocked, but rather than being a form of social control, Niederer and van Dijck (2010) argue that this is *protological* control, both social and technological. They argue that protological adherence to rules, through a combination of technical infrastructure and the collective wisdom of contributors underlies the success of *Wikipedia*.

Scholars of *Wikipedia* have shown that there are embedded hierarchies within this platform, and amongst users. Contributing administrators, registered users, anonymous users and software bots are ranked in an ordered system (König, 2013; Niederer & van Dijck, 2010) which determines and shapes their editing capabilities. Due to significant vandalism of the schizophrenia article, with the genetics section being completely removed on repeated occasions by one anonymous editor, regular editors applied for 'protected editing status' of the article, meaning that anonymous contributors would not be allowed to edit. All editors, regardless of their position in the hierarchy, must adhere to the rules for participation. In a *Nature* article on *Wikipedia* specifically addressing the schizophrenia page, a Wikipedian and neuro-psychiatrist Dr Bell claims that "disputes are settled through the discussion page linked to the entry, often by citing academic articles. 'It's about the quality of what you do, not who you are,' " (Giles, 2005: 901). Contrary to what Bell declares, we found that 'who you are' is important when it comes to editing the schizophrenia article. As König (2013) points out, legitimacy for editing is constantly debated amongst Wikipedians, in our case a group of people self-identifying as living with schizophrenia, doctors (including the neuropsychiatrist, Dr Bell), and other users. The negotiation of legitimacy became particularly evident when it concerned patient expertise. While some editors suggested their own experiences of living with schizophrenia reinforced the importance of their edits, others argued that such additions are anecdotal and biased, and not based on objective evidence. Protological use of rules comes into effect, as when one editor says to another "it's important that we not let your self-observations as a patient become SYNTH or OR". Later, in an exchange between the same editors:

> As much as I feel very sympathetic to what you have gone through, I think we need to be careful about what kind of a role we take on. It is worth reading WP:NOTGUIDE [wikilink – a hyperlink leading to a page within the wiki], which is very relevant to all of this discussion. (Tryptofish, 16:04, 27 July 2009 [UTC])

Not only is anecdote and personal experience discouraged from inclusion in the published articles, it is also discouraged from the talk pages, the purposes of which are defined as legitimating resource selection, not sharing stories. Editors are directed towards talk page guidelines if they bring too many anecdotes into their comments. The talk page is itself edited, with some editors removing personal stories, comments and discussion not related to building the article itself.

The *Wikipedia* article on schizophrenia, in particular schizophrenia genetics, is thus shaped by rules for participation and the protological following of these rules by editors, as well as by embedded hierarchies and the expertise of contributors. Priority is always given to the published scientific literature. As we demonstrate below however, consensus about this published evidence is not always easily achieved.

What is evidence?

> Evidence suggests that genetic vulnerability and environmental factors can act in combination to result in diagnosis of schizophrenia. Research suggests that genetic vulnerability to schizophrenia is multifactorial [wikilink], caused by interactions of several genes [wikilink]. (Schizophrenia article, *Wikipedia,* accessed 10 October 2011)

As outlined earlier, numerous articles have been published in leading scientific journals that claim to provide 'evidence' of genetic associations with schizophrenia. Despite this body of work, there is no consensus on the genetic basis of the disease, making it difficult for Wikipedians to provide an encyclopaedic overview of this area of controversial science. Single studies of associations, while fitting the OR rule, do not provide encyclopaedic-level evidence based on overview studies for a genetic association for schizophrenia. 'Curating' a list of publications runs the risk of drawing conclusions that are not in the original papers, and thus violating the SYNTH rule. These difficulties of curation are discussed and debated in the

> I tagged this article as 'confusing.' I did so even though I appreciate the amount of content it has. My concern is that there are so many hypotheses and anecdotes that it becomes difficult for the general public reader to navigate. Perhaps it would be better to decrease the large number of primary references and their often-anecdotal accompanying text, and limit the page to ideas that have been reviewed by secondary sources (Tryptofish, 22:04, 21 July 2009 [UTC]).
>
> I agree in part. There is no use in an article that is unreadable. But I think the state of the article reflects the state of science in this area and perhaps this should be made more clear in the introduction - that there are various hypotheses. It would be good to retain the comprehensiveness of the article though […] One thing we want to avoid is pretending that we are speaking authoritatively on an agreed upon and proven cause - which would be misleading (Notpayingthepsychiatrist, 08:13, 22 July 2009 [UTC]).
>
> I think we clearly agree more than we disagree. Just to clarify my point, though, I feel that, for the very reason that we, indeed, do not want to speak authoritatively on a single proven cause, this is more than just saying explicitly up front that there are multiple theories. Whether our audience includes those touched by the affliction, or also those from the general public who want to learn more, we owe it to them not to give undue weight [wikilink] to observations that exist as isolated anecdotes in the literature, even the academically peer-reviewed literature (Tryptofish, 17:02, 22 July 2009 [UTC]).
>
> I am with you wholeheartedly on the 'undue weight' issue... It is an article for general reading and an introduction to the subject and should parse in those terms, rather than have the look and style of a research paper. Of course, you do want it to be even-handed and not have the appearance of an introduction to the subject, and yet be an advocate of a certain position under the surface, as is, for instance, NIMH's position paper on schizophrenia, a different example of how it ought not to be done (Uniquerman, 19:25, 23 July 2009 [UTC]).

Box 1: Discussing the nature of evidence suitable for *Wikipedia* talk pages. The problem of the nature of evidence is highlighted in this excerpt from the causes of schizophrenia talk page:

> The professional literature contains a lot of primary publications that are anecdotal case studies; these are useful because they provide a database for subsequent analysis. But when a site like ours presents these cases as encyclopedic, we risk misleading the public by implying that they are significant evidence, when in fact subsequent scientific analysis may (or may not!) demonstrate that an isolated observation was a false lead. Thus the value of subsequent (secondary) scientific review. (Tryptofish, 14:46, 23 July 2009 [UTC])

The way in which the nature of evidence is constantly negotiated, whether experiential evidence or secondary reviews, with ongoing consideration of audience and the need to uphold neutrality, is also visible in Box 1, which gives sections of dialogue between editors conducted over 48 hours in July 2009.

Secondary analyses, or reviews, are constantly referred to as appropriate evidence. The very nature of 'review' is unclear in this context however. For example, one editor suggested including a recent study published in *Nature Genetics*:

> It's called *Exome sequencing supports a de novo mutational paradigm for schizophrenia* by Bin Xu, Maria Karayiorgou and several others. It costs $18. Can anybody who is actively working on this article afford to buy it? There are high level summaries in WebMD [hyperlink], Ars Technica [hyperlink] and elsewhere. Thanks. (SusanLesch, 9 August 2011 [UTC])

Another editor replies by referring SusanLesch to the MEDRS rule (Identifying reliable sources [medicine]), stating that: "we try to base all references on review articles especially for a topic with as much research as this one". The first editor writes back "That means that nobody can include this study [hyperlink], until somebody decides to write a review? I apologize for being impatient but the findings seemed rather important". The second editor replies:

> Not necessarily a review, but some sort of evaluative discussion in a top-level source, for example a 'perspective' piece in Nature or Science. Let me note that although this seems to me as well to be very interesting, the fact that it appeared in Nature Genetics rather than Nature suggests that there may be a few issues with it. The number of subjects, for example, does not seem huge given the statistical levels of difference being reported. We should really allow some sort of expert evaluation to take place before we try to include the study here. (Looie496, 17:18, 9 August 2011 [UTC])

These sections of talk show that editors are constrained in their edits not only by physical and financial access to the article but also by needing to wait for 'expert' evaluations of the literature, before such research can be included as evidence. As the talk demonstrates however, this kind of evidence is defined rather vaguely as "some sort of evaluative discussion in a top-level source". Attention to the reference list in the schizophrenia article at the time of our study revealed numerous citations that were not reviews, as well as one reference to another *Wikipedia* article (against rules) and also a schizophrenia forum discussion. Rather than a neat protological following of rules, what we find instead is a rather ad hoc assemblage of resources.

Closer examination of the structuring of the genetics section in the 'Causes of schizophrenia' article reveals how these additions accumulate in sequential order, rather than being coherently edited as a whole. An early paragraph in the genetics section details a 2003 review with seven genetic associations, and two 'recent' (2005 and 2006) reviews with evidence for another handful of genes. The text states that a number of other genes showed 'promising results' (with wikilinks given to genetic associations). A later paragraph in the same section states that the 'largest', most 'comprehensive' study of schizophrenia genetics actually disputed many of the findings mentioned in the previous paragraph, and that it was unlikely that the variations accounted for genetic risk. The next paragraph mentions the schizophrenia consortium we discussed earlier, with a meta-analysis (wikilink provided) showing nominal effects while subsequent text concerns copy number variants, endophenotypes and epigenetics. The article becomes a chronological patchwork of studies that nonetheless does have the effect of synthesising knowledge.

Controversy in action

Citation and curation of contentious knowledge online

Schizophrenia genetic science can be represented in multiple ways across different media. *Wikipedia* provides an ad hoc citation and curation of scientific resources, the selection of which is shaped by embedded hierarchies, protocols, expertise and access to literature. The discussions and negotiations amongst Wikipedians are visible for all potentially see. The internet is clearly an important medium for the exchange of scientific information amongst scientists, and also between science, industry, government and the public. But of course the infrastructural relations of the internet more broadly and of *Wikipedia* specifically are not neutral. Looking at the ways in which controversy appears across platforms helps to open the black box of the internet itself. Our analysis revealed citations-in-the-making, and the curatorial practices of actors who draw on resources in ad hoc and contradictory ways. The infrastructure of the internet enables these processes to be made more visible, and in this way provides an interesting counterpoint to the usual suggestion (Star & Ruhleder, 1994; Edwards et al., 2009) that infrastructure is only visible when it does not work. We found evidence in the *Wikipedia* talk pages of new kinds of interactions between patients, scientists, medical professionals and others, negotiating expertise and evidence, in ways which have not been previously possible in hospitals, clinics, laboratories, and other places where the classification, diagnosis and treatment of disease have been discussed. The visibility of the infrastructure and of the content makes these relations and interactions possible.

When sociologists of science began studying controversies in the 1970s, they studied them as experiments that opened up the formal hard shell of science to expose the "soft social inside filled with seeds of everyday thought" (Collins & Evans, 2002: 248). Controversies have always been enabled and enacted through communication media, although we argue that the internet facilitates this process, by making those 'everyday thoughts' visible in ways which were not previously possible. *Wikipedia* thus offers a more public viewing of 'controversy in action', of the ways in which actors select and use resources, that differs from the more closed-shop controversial work that goes into discussing the clinical relevance of genetic findings behind the closed doors of expert group meetings (Rabeharisoa & Bourret, 2009).

Different versions of schizophrenia genetics are enacted on *Wikipedia* through partial curation of resources. We have seen that contributors can utilise varied and often creative understandings of 'citation'. The citation is attempted to be used protologically on the *Wikipedia* pages, our analysis revealing a somewhat patchwork application of the *Wikipedia* rules. This ad hoc approach is partly a result of the sheer number of unreplicated studies being published in peer-reviewed journals, the ever-changing review articles in this area of science in top journals, and the constant stream of 'breakthroughs'. It is also shaped by the infrastructural specificities of the platform, being both enabled and constrained by them. In the talk pages for instance, it is clear that editors have difficulties not only in determining what is evidence, but also in finding resources. Many of the genetic research papers that are hyperlinked require subscriptions in order to access them. While subscriptions are shared between some Wikipedians, structural barriers exist for those who do not have access to these resources.[7] In many ways however, the resource at the end of the hyperlink is not always important. The hyperlink functions not only in directing the user to the resource, but also as a way of creating legitimacy by creating alliances which may not necessarily be two, or even n-way, but often one-way. This becomes important as we have seen that *Wikipedia* editors may only be linking to abstracts as evidence, within which the complexities of a scientific paper are not always evident.

Different versions of schizophrenia genetics are being represented on *Wikipedia*. In many ways, this could be considered as not surprising, because the definition, causes, diagnosis and treatment of schizophrenia have always been and continue to be deeply controversial. But in other ways, it is very surprising because in its rules of engagement *Wikipedia* tries to prevent controversy erupting on its pages. Below the surface of main articles, we observe debate and dissent. But we want to go further, and consider these not only as places where knowledge is distributed and knowledge claims are debated but also as places where knowledge is produced. *Wikipedia* is not just a collation of resources but a significant resource that has been curated, and in the process contributes to the production of knowledge.

Controversial knowledge production

The internet is an important source of information for individuals about health and illness, including schizophrenia. Informational websites such as *Wikipedia* have become popular sources of health information. In a 2008 article in *Social Science and Medicine* about schizophrenia websites (Read, 2008), the *Wikipedia* page was ranked third in Google, and second on their list of relevant websites (a Wikipedian recently informed his fellow editors that this ranking had, since the publication of the article, jumped to first place).[8] Scholars have argued that websites discussing schizophrenia aetiology offer an important service to the public, in presenting accurate, complex information (Read, 2008) on which people base potentially life-changing decisions. The prominence of *Wikipedia* as a source of information on schizophrenia leads us to consider its role not only in the representation of knowledge, but also in knowledge production.

The Wikipedians who contributed to the schizophrenia article were certainly aware of their audience, and the effect that their article may have on illness perceptions. For example, one editor promoted a more positive outlook about the disease, and argued for the use of neutral words such as ‘condition’ and ‘diagnosis’ rather than ‘illness’ and ‘disorder’, in order to help ‘recovery’. *Wikipedia* is considered by one of its editors to have an important role to play in educating doctors about schizophrenia, particularly regarding its classification, while another sees it as making a major contribution to understanding schizophrenia and research. While the NPOV page declares that *Wikipedia* ‘*describes* disputes’ but does not ‘*engage* in disputes’, our analysis reveals a more active engagement in the debates. The nature of *Wikipedia*’s involvement in controversy however, is partially determined by the scientific literature itself. While the speed of knowledge production on *Wikipedia* is often celebrated (Giles, 2005), our analysis showed that the publication of review articles in the major scientific journals remains a limiting factor when editing. Wikipedians thus continue to rely on more traditional forms of knowledge production, find it difficult to agree on what counts as reliable evidence when curating data, research findings and publications, and in this they are not dissimilar to professional scientists (Leonelli, 2012). Similar to the scientific review article (Hedgecoe, 2001), *Wikipedia* is a textual space in which knowledge is constructed.

Conclusion

In this article, we have shown how experts and non-experts come together on *Wikipedia* in order to produce knowledge that will be widely available. But this is not a free-for-all in which all utterances are treated equally. We have also shown that platforms, infrastructures and infrastructural relations are not neutral, but can reinforce established social positions. *Wikipedia* has clear rules which serve to structure and mediate what kinds of knowledge are (re)produced. We have demonstrated how knowledge from elsewhere is curated to create an easy-to-read entry. On *Wikipedia*, ‘reviews’ of the science are negotiated by Wikipedians who have varying degrees of access to the scientific literature. These curated spaces exist outside the core set of schizophrenia genetics research, yet rather than producing what Hedgecoe (2006) describes as an ‘alien science’ (an inaccurate view of the science by outsiders, based on the literature), we suggest that these actors negotiate, produce and circulate new forms of knowledge that is potentially global in its distribution.

The multitude of theories, methods, and research studies in the field of schizophrenia genetics means that each online representation of the science is not ‘inaccurate’ as such, but rather a partial ‘curation’ of resources in which material is selected, evaluated and presented. This results not only in the circulation of existing knowledge but also in the production of new knowledge.[9] We argue that the internet and the *Wikipedia* platform enable social action around the curation of these resources in ways which were not possible with earlier forms of communication technology, and features such as journal subscription fees and editing rights work to constrain engagement with the science. The infrastructural arrangements of sites such as *Wikipedia* also make these social actions more visible than they have been before, not only to STS researchers but also to the broader public.

The internet is well on the way to becoming black boxed, as the inner workings of computers and the means for connecting them are increasingly taken for granted. This only makes it more crucial to pay attention to how different platforms affect how patients, carers, scientists and medical professionals understand, interpret and engage with science. Our contention is that the internet is opening up new c/sites of scientific controversy shaped not only by consumers, patients, scientists, citizens, companies and doctors but also by technological infrastructure, which allows new interactions and makes actors' engagements with these controversies visible in previously unseen ways. By recognising that platforms such as *Wikipedia* can and may be used differently by actors, providing different kinds of information about an important topic, such an analysis aims to keep the black box open. Numerous STS researchers have broadened the spaces for examining the production of scientific knowledge beyond the laboratory, and in this article, we have contributed an analysis of another set of spaces in which controversies unfold.

This article relates to STS work concerning controversy, and the infrastructure of communication technologies, specifically connecting to previous work about schizophrenia genetics. By taking the online infrastructure as our starting point, we are able to follow how knowledge is curated and produced by those outside the 'core set' of scientific knowledge production. Unlike in the clinic, where categories of illness are attempted to be stabilised, or in journal articles, where coherent narratives are constructed, on the internet we see deliberate playing with the instability induced by controversy. The internet allows new spaces for analysis of controversy, each version, representation and argument shaped by actors and the infrastructure of the platforms. While we recognise that the internet, especially web 2.0 platforms such as *Wikipedia*, allows for new forms of engagement with science, we are cautious in celebrating what many regard as the emancipatory, democratic potential of this participatory engagement with genetic science. Instead we have examined how the internet affects and structures the ways in which controversies play out, and how that process sometimes stabilises and sometimes undermines existing knowledge, and sometimes generates new knowledge.

Notes

1 In their otherwise still excellent overview of different ways of studying controversy, Martin and Richards (1995) did not pay any attention to the medium of communication. They identified four approaches: positivist, group politics, constructivist and social structural; and compare them across six dimensions: epistemology, focus of analysis, conceptual tools, closure mechanisms, partisanship of analyst, and decision-making procedures. They recognise that no single study of controversy will fit neatly into one of these ideal types. Our analysis fits somewhere between constructivist and social structural, especially as our focus of analysis is the content and medium of communication in which both those inside and outside the scientific community take part.

2 The material has been stored offline by the authors, and can be consulted by appointment.

3 Our analysis leaves open questions and areas for further research. We still know little about *Wikipedia* editors. There are many other internet spaces which need further research regarding their role in controversy, such as the websites of companies selling genetic tests, mental health blogs, Listservs, fora and video sharing sites. In the case of schizophrenia genetics for example, user fora in particular could potentially provide an important resource for understanding how patients and consumers share resources, as well as genetic data, phenotypic information and illness experience, these forms of knowledge engaging with, contradicting and replicating biomedical understandings and scientific research. Ethical questions arise when considering contacting, quoting from and engaging with fora in research, highlighting the controversial nature of conducting internet-based research, especially about sensitive topics such as mental health.

4 In the DSM-5, published in May 2013, the diagnostic criteria for schizophrenia were adjusted in order to try to increase the reliability of diagnosis. Sub-types have been eliminated, instead clinicians are advised to focus on the severity of individual core symptoms, including hallucinations, delusions and disorganised speech. Available at: http://pro.psychcentral.com/dsm-5-changes-schizophrenia-psychotic-disorders/004336.html (accessed 4.9.2015).

5 For example, Suchecki and his colleagues (2012) have visualised the bottom-up categories generated by Wikipedians with the top-down determined categories used by the Universal Decimal Classification used in many libraries. The latter devotes over 70% to science-related topics while in *Wikipedia*, topics related to arts, entertainment and sport are much more highly represented. See the visualisation at: http://www.scimaps.org/detailMap/index/design_vs_emergence__127 (accessed 10.9.2015).

6 This was stated by Jimmy Wales, one of the founders of *Wikipedia*, during a public meeting held on 15 January 2015 at the Royal Netherlands Academy of Arts and Sciences, Amsterdam.

7 One of the much-touted advantages of open access publication is precisely to make scholarly publications available to everyone with an internet connection (see Meyer, 2013).

8 The results provided by *Google* and other search engines are subject to enormous variability, depending on the search history of the user, the machine on which the search is conducted, the filters installed by administrators, and many other factors. Nonetheless, when searching using different search engines on 6 August 2013 and again on 25 April 2015, two of the authors also consistently received *Wikipedia* amongst the top three results.

9 As Lynch et al. (2008) point out, the US legal system seems to encourage scientific dissent in the ways in which new scientific techniques are admitted as evidence. The internet has certainly magnified the possibilities for 'ersatz scientific dissent' as well as for junk controversy.

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A measure of 'environmental happiness': Infrastructuring environmental risk in oil and gas offshore operations

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Abstract

We know little about the marine environment, particularly in the inhospitable Arctic region. Whereas national authorities often rely on the construction of a solid knowledge base to allow human activity access to new areas, scientists point to the impossibility of building comprehensive knowledge of subsea ecosystems. This paper presents an ethnographic study of a Norwegian oil and gas company's development of a knowledge infrastructure for measuring the long-term trend of the behaviour of the marine environment, i.e. a baseline to be used as a reference to calculate potential risks in a commercially relevant Arctic area. The company's *infrastructuring mechanisms* involve selecting and configuring environmental sensing technologies, and tying them into the fabric of the company's operational analysis routines. We identify and discuss how these mechanisms address and articulate temporal, spatial, and social tensions and how, in so doing, they mould new representations of environmental risk.

Keywords: knowledge infrastructure, infrastructuring, environmental risk

Introduction

November 2013. We are sitting in the office of an IT advisor in the research centre of a Norwegian oil and gas company. The advisor is leading the development of a web portal used by the company to display several real-time environmental parameters measured from a subsea observatory on the seafloor offshore northern Norway. The data indicate the salinity, temperature, chlorophyll level, pressure, and depth of the water. There is also a graph representing the biomass concentration in the water column, which is updated every few minutes, and a video made from pictures over the last two days. These pictures are obtained using a camera placed next to a coral reef. The IT advisor has an Internet browser open on one of his two PC screens and an instant messaging program on the other screen. While explaining something to us, he is suddenly distracted by the blinking of the *messaging program. One of the programmers working on the web portal wants his attention because "the fish is back". The advisor turns to the browser, opens the web portal, and looks at the video frame, where a fish has just appeared in front of the subsea camera. It floats calmly, looking at the camera lens for a while, and finally leaves. The advisor explains that it is not the first time that fish has behaved in that way. An analysis of the acoustic measurements previously indicated that that fish also speaks to the camera:*

> And that's what happens, he gets really angry. So he says "Shshshshsh!" (…) Or maybe he gets annoyed. Maybe he gets used to it. And that's also one of the things. Will we [have an] influence? Will the local fauna get used to the sounds when we do the stuff? (Excerpt from field notes)

A Norwegian research magazine was recently titled "*We know the moon better than the seabed*" (Haugan, 2015). In this paper, we tell a story of infrastructuring a baseline of the seabed. We recount of a project by a Norwegian oil and gas company (NorthOil, a pseudonym) to perform real-time environmental monitoring in the sub-Arctic marine ecosystem off the coast of north Norway (Venus, a pseudonym). Venus is estimated to be rich in petroleum resources but is the only portion of the Norwegian continental shelf (NCS) where oil and gas operations are currently banned. NorthOil's goal is to build an approach to continuously survey several environmental parameters in order to obtain a robust baseline, i.e. a reference long-term trend of the behaviour of the Venus ecosystem. This approach could put NorthOil in a better position to obtain permission to operate in the event of a future opening.

NorthOil's initiative is motivated by the Norwegian government's promotion of a knowledge-based approach for making decisions that can potentially affect the environment (NME, 2009). This technocratic perspective implies monitoring environmental parameters over a long period to obtain a baseline, but it remains uncertain whether it might lead to robust knowledge and thus to input for risk assessment. The situation is complicated by heated political and scientific debates around the uncertainties associated with the environmental impact of oil and gas offshore operations. Scientific institutions have particularly criticised the knowledge-based approach for its shortcomings, arguing that comprehensive risk assessment is ultimately impossible:

> [U]ncertainty cannot fully be quantified when facing ignorance – what we do not know, and even further: what is beyond our conception of what is possible. (Hauge et al., 2014: 87)

Subsea environmental monitoring practices within the oil and gas sector are not new, but they are usually confined to annual or triennial sampling campaigns conducted by external consultants. Datasets are normally sparsely stored in disconnected data silos with data analysis trailing data collection by months or even years. What makes NorthOil's strategies different is that they consist of a combination of tightly interacting remote sensors, desktop systems, risk representations, and work processes. For the newly acquired capacity of NorthOil to have organisational uptake, the strategies draw on existing operational routines, but they must be adapted to a domain that is largely unknown to the oil and gas sector. What becomes apparent, then, is an effort of innovation and experimentation at the fringes between operation-based monitoring and long-term environmental monitoring. At these fringes, our (non-)knowledge of the marine ecosystem is translated into numeric trends that must be understood by an oil and gas audience. We therefore want to enquire into this moment: *How is uncertainty about the marine environment quantified into a baseline of environmental behaviour? How are the emerging tensions addressed in practice?*

Studies into the problem of long-term data collection and curation demonstrated how data are constructed and never result from uncontested processes (Borgman et al., 2012; Ribes & Jackson, 2013; Steinhardt & Jackson, 2014): the very definition of 'data' hides invisible actors and values on technical, practical, and political grounds (Bowker, 2000; Bowker & Star, 1999; Gitelman, 2013). The literature in Science and Technology Studies (STS) has successfully treated cases where data are produced through localised practices – even when they are part of larger arrangements. We present a case where the problem of building a long-term trend of environmental behaviour prior to and during an operational deployment (a baseline) prominently emerges from the interaction between remote distributed measurements and the portfolio of corporate ICT, routines, and values (Edwards, 2010; see also Monteiro et al., 2013). In so doing, we relate to and extend the literature in STS problematizing the co-evolution of knowledge infrastructure and its objects of interest (Bowker & Star, 1999; Ribes & Polk, 2015) and demonstrating that our knowledge of nature is inextricably entangled with the infrastructure that we use to gather data about nature (Bowker, 2000; Edwards, 2010). We specifically investigate how NorthOil is establishing a monitoring infrastructure through three mechanisms: *sensoring*, the bricolage work towards the improvisation and adaptation of acoustic sensors to detect marine biomass; *validating*, the workarounds to ensure that measurements can be trusted and routines can be found to handle them; and *abstracting*, the pragmatic adjustments to make risk representations appropriate to existing routines. These infrastructur*ing* (Karasti et al., 2006; Star & Bowker, 2002) mechanisms showcase the oscillation between local, real-time measurements in Venus and the need for the results to travel to be understandable and significant across and outside the infrastructure over the long term.

Even though NorthOil's effort is directed at knowing nature in an undisturbed environment, it is still embedded in the oil and gas operational context and monitoring tradition. We show how the infrastructuring mechanisms modulate this embeddedness along the time, space, and trust dimensions. '*Shshshshsh!*' is translated through the spatial and temporal framing performed through NorthOil's knowledge infrastructure. This is, however, not enough for the fish's voice to be *heard*. We further contribute by showing that the monitoring infrastructure must also be weaved into a careful work of social infrastructuring (cf. Bowker, 1994), based on techniques to build trust rather than consensus (cf. Barry, 2013). These techniques are a purposeful mix of social networking with directly useful stakeholders, and of open data sharing to create momentum around the new infrastructure. We thus discuss the relation between infrastructuring and environmental risk perception and show that NorthOil's mechanisms construct environmental risk as a public problem in a way that makes business sense in the context where NorthOil operates. We conclude that '*Shshshshsh!*' has a potential to mean different things – or nothing at all – based on the political and economic context of infrastructuring.

Theoretical background

From uncertainty to risk quantification

Social scientists have been interested in the relationship between uncertainty and risk quantification in terms of its political, economic, and social connotations (Beck, 1992; Jasanoff, 1999). Technical routines of quantitative risk assessment always embed socio-political assumptions (Jasanoff, 1999). Consequently, risk is not an external object that can be measured; it is instead a reflection of our (evolving) knowledge (Beck, 1992). We rely on Latour's (2003) interpretation of Beck's concept of 'risk' as a *network* of distributed relations between social, technical, and natural elements. A vivid example is the case of the 'mad cow' disease:

> [Y]ou begin with a T-bone steak on your plate and you end up in the laboratory of a protein specialist showing you the tertiary structure of the now infamous prion (…) But in the mean time you have visited European Commission bureaucracies, the cattle farmers' unions, quite a few hospitals, and participated in a lot of scientific meetings. (Latour, 2003: 36)

In sum, definitions of 'risk' contain an inherent tension between global visibility and local conditions that make it possible and measurable in practice (Latour 2003). Risk is constructed, it emerges through constant negotiations between what can be known, viz., sensed, represented, and valued. Currently, the translation of the uncertainty into the language of risk management has become a constitutive feature of corporate governance, where the underlying idea is that well-governed companies are those that are able to handle risks properly (Power, 2007, p. 7; cf. Jasanoff, 1999):

> Uncertainty is therefore transformed into risk when it becomes an object of management, regardless of the extent of information about probability.

This is certainly the case when we speak of *environmental* risk. However, scholars in the field of marine policy, notably, those from the Norwegian Institute for Marine Research (IMR), have argued against the possibility of actually defining and quantifying environmental risk on an epistemological level (Blanchard et al., 2014; Hauge et al., 2014). Ecosystems are never unambiguously given, but the 'facts' that constitute a baseline of natural behaviour are constructed through categorisation processes and are fed into governance, which is often, in turn, driven by financial reasons (Knol, 2013).

Several studies in marine policy also emphasised the networked nature of environmental risk assessment (Blanchard et al., 2014; Hauge et al., 2014; Knol, 2013). A complex relationship exists between socio-political choices and their environmental consequences. Some authors have stressed the need to investigate this relationship in terms of the uncertainties associated with the side effects of routine operations rather than with major accidents, such as large oil spills (Blanchard et al., 2014). This perspective opens the black box of the connection between the less visible details of quantitative risk assessment procedures and how knowledge emerges: the former can restrict the debate on the issues and uncertainties that are considered relevant when deciding the scope of risk assessment, the methodologies, and the presentation of results (Hauge et al., 2014). Crucially, then, our perception of environmental risk is influenced by risk assessment methodologies:

> All these choices are value-laden because they have the potential to influence perceptions on what is at risk, how high the risk is, and what ought to be done with regard to the issue. (Hauge et al., 2014: 88)

To summarise, the analysis of the process of feeding uncertainty into risk requires a theoretical concept able to account for the networked and long-term dynamic relations between social, technical, and natural elements. We believe that this problem should be addressed as one of knowledge infrastructure.

From knowledge production to knowledge infrastructures

Our knowledge inevitably depends on the apparatus that we use to know the world (Barad, 2003) and co-evolves with it (Bowker, 2000). The data that we collect and that constitute the base of our knowledge are always cooked, never entirely raw: "Raw data is both an oxymoron and a bad idea. On the contrary, data should be cooked with care" (Bowker, 2005: 184). For STS researchers it is important to look "under the data", at the practices to *produce* rather than discover knowledge (Gitelman, 2013), by investigating empirically how techniques for data collection and curation become constitutive of scientific facts (Bowker & Star, 1999; Chang, 2004; Pinch & Bijker, 1984). Ribes and Jackson (2013) describe the non-heroic workarounds of sampling and measuring river water quality while also balancing concerns about the long-term usability and readability of the data for future research. Bowker and Star (1999: 36) illustrate what this perspective entails: "While pregnant cow's urine played a critical role in the discovery and isolation of reproductive hormones, no historian of biology had thought it important to describe the task of obtaining gallons of it on a regular basis". Scientific data curation is often the result of collaborative routines, which strictly depend on the members trusting the value of each other's data because what counts as data to one scientist might be context to another (Borgman et al., 2012). Often different temporal perspectives drive the scientists' daily work practices. Steinhardt and Jackson (2014) focus on the alignment work to bend different temporal perspectives to accommodate the activities of different groups. Observing how rhythms are prioritised gives us an understanding of otherwise invisible relational dynamics. The spatial dimension of data production also deserves attention. In a case from a domain similar to ours, Almklov and Hepsø (2011) describe how mismatching interpretations of petroleum reservoirs are generated by geologists and geophysicists, who are accustomed to examining geological sedimentation in opposite directions, the latter from the top (by reading electric logs) and the former from the bottom (by studying rock layers).

In sum, these studies have shed light on the material enactment of data, front-staging issues of *trust* (Borgman et al., 2012), *time* (Steinhardt & Jackson, 2014), and *space* (Almklov & Hepsø, 2011). They have successfully demonstrated how data construction is part of a larger arrangement of communities and information tools, but data acquisition often has a situated character: e.g., a point in a river stream (Ribes & Jackson, 2013) or a pregnant cow (Bowker & Star, 1999: 36). NorthOil's approach to data construction is peculiar because it is only made possible through an ecology of distributed devices and systems, each with a different origin and genesis, made to interoperate through the constant and not necessarily always successful work of maintenance, upgrades, and adaptation (Edwards et al., 2013; Monteiro et al., 2013). We thus supplement the findings of the literature reviewed above with those that explicitly focus on how the *knowledge infrastructure* matters to fact constructions. Relevant examples originate from heterogeneous fields, such as the petroleum industry (Bowker, 1994; Østerlie et al., 2012), energy provision (Silvast et al., 2013), climate science (Edwards, 2010), medical practice (Jirotka et al., 2005) and research (Ribes & Polk, 2015), and environmental research (Karasti et al., 2006; Karasti et al., 2010). Some of these studies investigate the evolution of infrastructures by observing the work to balance immediate and situated needs with the uncertainties associated with long-term and global constraints (Karasti et al., 2010; Ribes & Finholt, 2009). To embrace the evolving and unstable nature of infrastructures, Star and Bowker (2002) used 'infrastructure' as a transitive verb. Thus, the term *infrastructuring* (Karasti et al., 2006) was introduced to refer to the reflexive strategies of designers and users to make infrastructure flexible to meet tensions and anticipate future problems. Infrastructuring avoids clear-cut categories of system development, use, and maintenance where infrastructure evolution does not quite fit.

Nevertheless, our knowledge still crucially depends on the experience in a local context (Zimmerman, 2008). Edwards (2010) describes the making of a climate science infrastructure as a matter of simultaneously conducting local measurements into planetary climate data networks and processing dirty datasets into consistent and readable representations. Hence, the making of imperfect data models has a fundamental role in constituting reality, rather than describing it. NorthOil's experimentation unfolds along a similar vein. A methodological perspective to tackle the tensions generated by infrastructure evolution involves inverting the infrastructure. *Infrastructural inversion* is similar to a 'pair of glasses' for the actors in the field as well as for the researcher to move the focus from situated instances of technology development towards the continuous articulation work to upgrade and maintain the infrastructure (Bowker, 1994; Bowker & Star, 1999; Edwards, 2010). Inversion is a powerful tool for looking "under the data" and exposing the inner mechanisms of infrastructuring knowledge production. For the actors, inversion is a generative resource to "reinterpret the status quo of infrastructure in light of potentialities, thus paving the way for embedding new tools in particular ways" (Kaltenbrunner, 2014: 19).

In the case of NorthOil, however, old habits and practices die hard. Partly because of a focus on safety, oil and gas operations are fairly conservative and slow to adapt. Against this backdrop, ongoing experimentation to create an environmental risk-monitoring infrastructure creates space and opportunities to explore how environmental risk will be rendered for heterogeneous audiences; on the other hand, it also presents challenges in terms of the appropriation or institutionalisation of tools, practices, and formal procedures.

Case

The NCS and the uncertainties of environmental monitoring

The waters off the coast of Norway are home to the world's largest population of a species of cold-water coral called *Lophelia pertusa* (Fosså et al., 2002). The corals are centres of complex marine ecosystems, where fish and other marine species seek shelter and food (Costello et al., 2005; Figure 1). The waters off the Lofoten and Vesterålen Islands in north Norway (Venus) host some of the world's largest stocks of fish, particularly cod and herring, which migrate there from the Barents Sea to spawn. Their eggs and larvae later drift back towards the Barents Sea following the water currents (Hauge et al., 2014). In addition to the substantial economic interest in the region going back thousands of years, the coastline is scenic and attractive for both tourism and recreation.

Figure 1. Fish swimming over a coral reef. Photo: MAREANO/Institute of Marine Research, Norway.

Since the discovery of hydrocarbons in the North Sea in 1969, there has been constant controversy between fishery and environmental concerns on the one hand, and oil and gas operations, on the other. Alongside this debate, the oil and gas sector in Norway has developed an intricate network of rigs, platforms, pipelines, vessels, and fibre-optic cables to explore, extract, and produce resources. Currently, 78 oil and natural gas fields are active in Norwegian waters (MPE, 2014), which are home to thousands of wells (Figure 2). The socio-economic significance of the oil and gas sector represents approximately 25% of the GNP (SN, 2014), is the largest export, employs approximately 15% of the non-public workforce, and has accumulated one of the largest governmental investment funds in the world.

The constant hum of controversy surrounding oil and gas operations in Norway is regularly accentuated by particularly antagonistic issues. The present issue of whether to allow oil operations in Venus, which is the richest fishing ground in the country, is a perfect example of such controversy (Blanchard et al., 2014; NME, 2006). The pressure to open the areas relates, among other things, to the estimate that approximately 24% of the world's undiscovered oil and natural gas resources are hidden in the High North, above the Polar Circle (Hasle et al., 2009). Norway is one of the five countries having territorial claims in those areas, which are characterised by harsh weather conditions and environmentally sensitive habitats. Little or sparse knowledge exists about the behaviour of these habitats and on the possible effects of oil and gas activities. The Norwegian Ministry of Climate and Environment has adopted a knowledge-based approach in its decision-making processes. Its aim is to acquire a 'reasonable' baseline for assessing the risks associated with human activity, including fishing, tourism, and oil and gas operations (NME, 2009: Section 8):

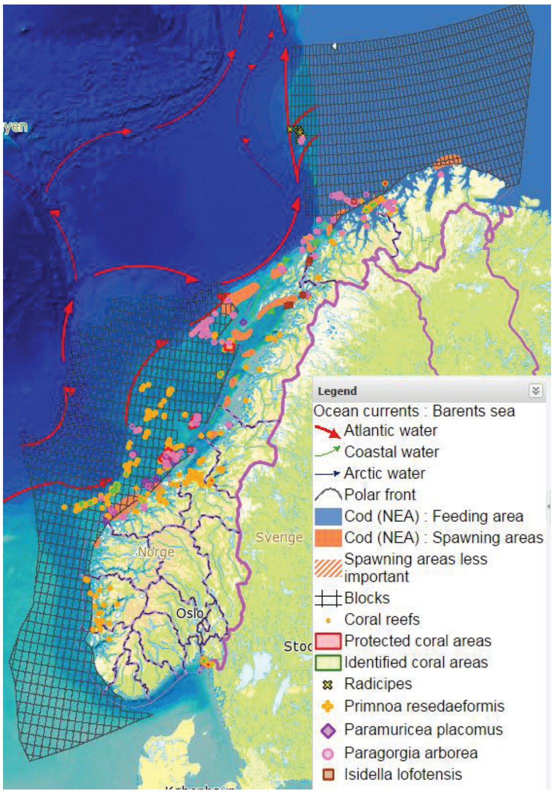

Figure 2. The Norwegian continental shelf, where the operational blocks assigned by the Norwegian government (grid) overlap with the environmental resources. Credit: MAREANO/Institute of Marine Research, Norway.

> Official decisions that affect biological, geological and landscape diversity shall, as far as is reasonable, be based on scientific knowledge of the population status of species, the range and ecological status of habitat types, and the impacts of environmental pressures. The knowledge required shall be in reasonable proportion to the nature of the case and the risk of damage to biological, geological and landscape diversity.

In making a provocative statement to emphasise that there can be no 'reasonable' scientific background behind environmental risk assessment calculations, the IMR argued that "between 0 and 100 per cent of a cohort of fish spawn can be lost in an oil spill" (Helgesen & Tunmo, 2009). Oil and gas companies have in turn criticised scientists for exaggerating precautionary considerations in the risk calculation process.

Today, risk mitigation measures are generally used by oil and gas companies operating on the NCS in a reactive manner by following regulations that were set in advance by authorities and politicians (Hasle et al., 2009). However, these regulations are often indefinite and general (Hauge et al., 2014). The Norwegian Directorate for Nature Management argued that the risk models developed for the areas offshore of north Norway are unable to account for local conditions, e.g., narrow fjords, local currents, tides, and wind (Strand, 2014).

Disagreements about the possibility of turning the environment into baseline behaviour are due not only to spatial consideration but also to the observation that the environment does not respond to the same temporal scale of industrial activities. The time scale for offshore drilling engineers is seconds and minutes when responding to sensor-based pressure, torque, temperature and directional measurements. Companies seek an operational window that is as wide as possible while remaining constrained by the slow and formal decision hoops that every new technology must jump through in an oil and gas organisation. However, environmental trends and effects may only become visible over years, decades, or even centuries. The corals have existed on the NCS for at least 9,000 years. Pollution on fish spawning products becomes visible only in the next generation, when cod larvae could die after 3–4 years. Fish generations are the concern of fishermen, who want to have knowledge about the present population and to ensure that there will be fish to catch in the subsequent seasons. When asked about the tension between a real-time approach to risk assessment and long-term natural changes, one NorthOil environmental chemist wondered if it makes sense to frame the environment in human-constructed patterns:

> That's a potential paradox, of course, but I guess that the easy, the obvious answer is that (…) you need to start to monitor early (…) when you start doing what you could define as a baseline, 'cause then it's not really a baseline. But then another existential question: Is there such a thing called ecological baseline? Is that possible? Because no environment is constantly… constant over the whole time.

The Venus observatory

NorthOil is the primary oil and gas operator in Norway. Founded in the early 1970s, the company was historically organised around a geographically local operational site. Currently, NorthOil is promoting the development of cross-disciplinary and cross-geographical infrastructures, which are supported by the installation of collaborative work technologies (e.g., SAP and Microsoft SharePoint) and fibre-optic Internet connections that allow for faster communication between offshore sites and onshore control centres.

Given the strategic location of Norway relative to the High North, NorthOil decided to start collecting oceanographic parameters halfway between the more familiar Norwegian Sea and the unwelcoming High North. In collaboration with marine research institutes and technology vendors, NorthOil installed an ocean observatory in the mid-2000s on the seafloor in the Venus area, approximately 20 km off the Lofoten Islands, above the Arctic Circle. The observatory consisted of a metallic semi-conic structure equipped with a few off-the-shelf sensors to detect basic environmental parameters such as sound, pressure, temperature, turbidity, chlorophyll, and floating biomass. A camera and a camera flash were placed on a 2-meter-high satellite crane to take pictures of a coral reef that was selected by project participants.

The project was considered successful and strategically relevant; therefore, it received funding in 2011 from the production and development department of NorthOil. In 2013, the observatory was connected to the shore with a fibre-optic cable. Environmental data began to be fed into a publicly accessible web portal in real time (Figure 3). An environmental advisor from NorthOil summarised how they could use the data to demonstrate their ability to drill safely and increase the operational window as follows:

> We want to look at different types and possible technologies or methods to get this done. (…) If we can argue that we can measure when the biomass comes, either when fish come or go or when the spawning products return, we can stop drilling on time before the products return.

NorthOil was interested in using real-time data to find a correlation between the time of year and the marine biomass concentration (fish, eggs, and larvae). By analysing the trends over several years, a threshold value could be obtained to indicate the beginning and end of the spawning season. Therefore, the operational window could be set outside this interval.

Research method

This paper is the result of a longitudinal ethnographic study conducted within NorthOil. Even in the traditionally open Scandinavian environment, access to an oil and gas organisation is not straightforward for external researchers. The first author was granted a pass to NorthOil's R&D department through one member of our research team who also holds a full-time senior position at NorthOil and has a history of collaboration with the second author.

Beginning in April 2012, the first author spent an average of 2–3 days per week for two years at the field site. She was initially granted a desk at the entrance of the department, where projects related to environmental monitoring were happening. However, sitting next to the entrance is equivalent to having a 'guest' label. Not all information is shared with guests. As the researcher began to take part in some meetings and to follow a few informants to coffee breaks and lunch breaks, the employees became more accustomed to her presence. In November 2012, the head of the section, who initially granted the researcher a badge, also allowed her to use a desk in an open-space office shared with key participants in NorthOil's real-time environmental monitoring programs.

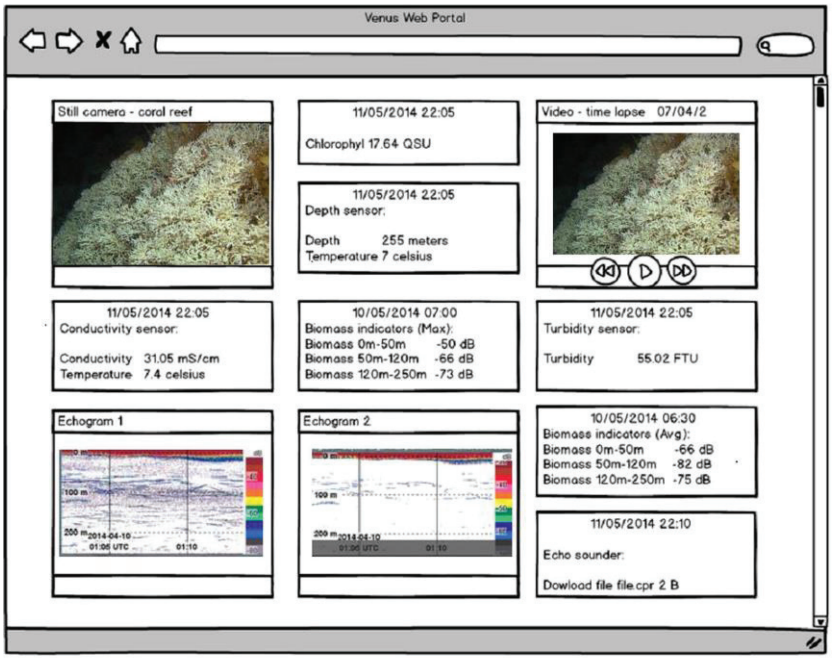

Figure 3. The Venus web portal. 'Biomass indicator' is the environmental value (reproduction by the authors with www.Balsamiq.com). Photos: MAREANO/Institute of Marine Research, Norway.

Along with this physical vicinity, access to information was greatly increased. Corporations today often hire ethnographers to collect qualitative data on the functioning of daily work (Hepsø, 2013). This habit makes the subjects in the field more comfortable with being observed, but it does not guarantee an easier life for external personnel. To blend with informants, the researcher regularly went to the office on days dedicated to fieldwork at approximately 8:30 and left after 16:00, as did other employees. Together with the constantly visible NorthOil badge, this approach allowed the researcher to intermingle with the people who were working in the department. In fact, she was sometimes mistaken for a full-time employee. She was often invited to meetings, workshops, and teleconferences with external partners and technology vendors and with other NorthOil offices located elsewhere in the world. Observations have been continuous (producing hundreds of pages of field notes) and fundamental for identifying internal documentation (reports, presentations, and deliverables) and informants to interview.

Semi-structured interviews (33 in total) were initially conducted with NorthOil representatives and later with representatives from other companies that were collaborating with NorthOil, namely nine environmental advisors from a company active in risk assessment and quality certification and one project manager from a technology vendor company. We travelled a few times by plane to personally interview people located in other Norwegian cities. The second author could also participate in several events and in the interview process. Data collection occurred regularly until April 2014. Henceforth, the first author has only occasionally visited the NorthOil R&D department to conduct short follow-up discussions regarding the themes emerging from the data analysis process.

The data analysis proceeded in parallel with data collection and was aided by a discussion between the two authors and with the members of the research group. In line with an interpretive tradition stemming from the field of Information Systems (Klein & Myers, 1999; Walsham, 1995), we relied on several iterations to make sense of the empirical data. Initially guided by our research question, we searched for practical mechanisms with which to build a baseline of the unknown subsea environment in Venus. The iterative analysis guided our attention to shift from the artefacts (web portals, sensors, and subsea observatories) to the infrastructures that sustain these artefacts across space and time (Edwards et al., 2013; Monteiro et al., 2013). In doing so, we operationalised an infrastructural inversion (Bowker, 1994), which has influenced our data access, collection, and analysis strategies. However, this approach tends to leave its dynamics underspecified, particularly when the investigation of infrastructure is primarily in the hands of a single researcher for a limited number of years. For example, how could we understand the way the effort of building a new knowledge infrastructure is concerned with problems of accessing the sea floor? How could we know about NorthOil's existing routines for handling real-time datasets? Following the suggestions of Ribes (2014) and Beaulieu (2010), we identified key relevant actors in the field and aligned with them because we realised that they sought to answer the same questions that we were. This strategy was facilitated by our increasing familiarity with the actors. As a result, we were sometimes asked for feedback or for help with small tasks in the Venus project (e.g., commenting on a draft document).

Findings: Three infrastructuring strategies

The literature identified a number of concerns associated with the processes of data collection and maintenance, such as data sampling (Ribes & Jackson, 2013), long-term curation (Karasti et al., 2006), and validation and modelling (Edwards, 2010). We identified three similar difficulties encountered by NorthOil: (1) establishing routines to generate measurements of the marine ecosystem; (2) investigating existing standardised mechanisms to validate the trustworthiness of the datasets collected in unmanned locations; and (3) attempting to abstract the datasets into general representations of environmental risk that make sense for the oil and gas professionals. We call the strategies enacted by NorthOil to overtake these difficulties *infrastructuring mechanisms* because, more prominently than other examples in the literature, they are only made possible through the infrastructure as a whole. At the intersection between environmental monitoring and operation-based monitoring, these infrastructuring strategies encompass phases of selection and design, installation, adaptation, and use, and result in an amalgam of institutionalized and new information systems, devices, routines, and locations. As we shall see, these mechanisms encapsulate a range of infrastructural concerns inside the representations of risk for the marine resources.

Sensoring

The monitoring of the subsea environment over the long term – viz. outside daily operations such as drilling and producing – is not a core activity for oil and gas companies. NorthOil and its partners took inspiration from actors with established experience on and in the sea, primarily fishermen and external marine research institutions, including the IMR. The adaptation of their technologies to the Venus project, however, soon gave birth to new situated problems.

The sensors installed on the observatory were rather inexpensive off-the-shelf devices. Particularly significant were the active acoustic devices such as echo sounders. In principle, echo sounders send an acoustic pulse at fixed intervals (shorter than 1 s) and measure the strength of the signal returned when a target is hit within its audible range, which depends on predefined settings and on the speed and direction of the water current. In general, these instruments can be used to determine the size of the targets in the water column, such as fish, fish eggs, larvae, or even zooplankton.

A first challenge for the Venus project was that targets as small as zooplankton or fish larvae and eggs were almost impossible to locate because they are smaller than the wavelength of the echo sounders available to the Venus project. As a consequence, computer models simulating the dispersion of eggs and larvae drifting along with the water currents were integrated to obtain the missing data. A marine biologist from a company collaborating with NorthOil described this challenge:

> One example is that we want to monitor larvae and eggs drifting through the bottom masses; but (…) [w]e know [that the Venus ocean observatory] is not able to monitor that. So what do we do then? (…) The equipment will be better in a few years perhaps, 'cause we know that there are organisms that are vulnerable to oil pollution, much more vulnerable than adult fish, that can swim away from the oil, but [larvae can't].

A second challenge related to the positioning of the acoustic sensors. These instruments are typically installed on fishermen's boats and point downwards.

Placing the acoustic devices on the seafloor means that the new measurements are obtained

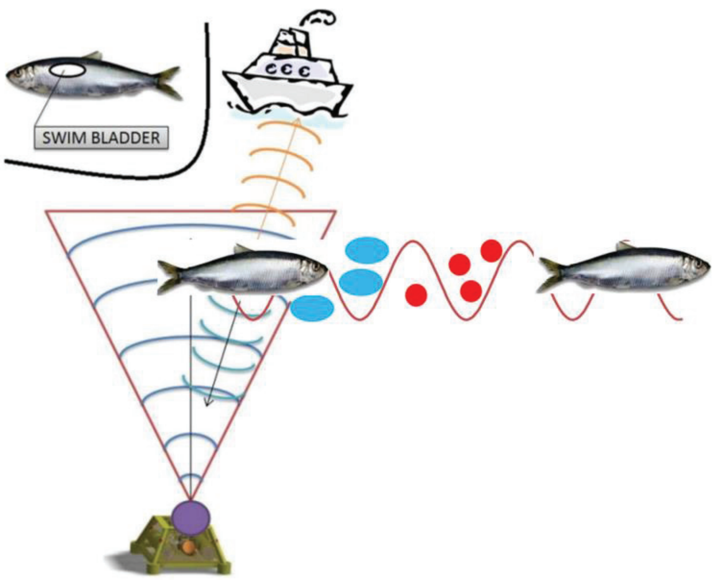

Figure 4. Approximate position of the swim bladder (top left) and exaggerated schematic representation of two directions used to spot fish (from the seafloor or from a boat). The sound waves are often unable to spot targets smaller than their wavelength. Source: authors' drawing.

from the bottom up rather than from the top down (Figure 4). This approach had an unpredicted consequence because the way in which upward-looking data should be interpreted is not obvious. The most audible fish for an acoustic device are those that have a swim bladder, an internal organ located in the dorsal portion of some fish species that not only allows them to control their buoyancy but also to emit and receive sounds. These fish reflect a stronger signal and are thus easier to spot, but the way that the swim bladder reflects the signal depends on the orientation of the acoustic sensor. Given that time series collected by other research institutions or by fishermen have generally been taken from the top down, the Venus data were not directly comparable with the historical datasets available to NorthOil and its partners. An environmental advisor from a partner company involved in NorthOil's project summarises as follows:

> [A]nother problem about the [Venus project] is that the fish experts don't have any experience about having the sensors from the bottom, that goes from the bottom. So they don't know the echo actually from the [underbelly] of the fish.

In sum, the production of a long-term and global picture of the subsea life in Venus was struggling to cook its data and move past very situated issues involving spotting a fish, an egg, or zooplankton. Networking with the existing infrastructure of research institutions and fishermen proved useful to produce – or to *not* produce – some initial measurements that, in their imperfection, began to draw the boundary between what constitutes a baseline of the marine ecosystem and what does not (e.g., small fish without a swim bladder).

Validating

Large-scale industry depends on predictability and quality assurance to run its business. Especially because the sensors were placed at unmanned subsea locations, the Venus datasets had to undergo validation steps. However, how can one quality-assure the environment?

One solution involved rendering the environment in a format that fitted industrial reporting routines. A few NorthOil members close to the Venus project decided to investigate the routines that the company adopts to handle real-time data during an oil and gas company's daily operations, for example, when a new well is drilled. The idea was to borrow insights and to adapt those routines to the environmental domain. As is the case for many oil and gas companies, NorthOil has a dedicated support centre (called here Online Support Centre, or OSC) whose scope is to determine the technical quality of the data gathered by the service companies in charge of the drilling operations on behalf of NorthOil. The drilling of a new well is a delicate phase that must be carefully monitored to prevent accidents that can range from a stuck drill pipe that halts operations for a few days and causes the loss of huge amounts of money to more serious consequences for the surrounding environment. However, knowing if things are going right or wrong is a challenging task when there is a lack of references against which to decide whether a given measurement respects the safety intervals. One OSC engineer stated that some errors can go completely unnoticed, generally due to sensor calibration:

> It could be that the data are shifted for some reason. Let's say that the whole dataset coming in is 5 metres too deep or 5 metres too shallow. We wouldn't be able to notice that (…) and that could be due to a calibration error to the sensor.

The OSC relies on both situated workarounds and standardised approaches to overcome these tricky issues. A typical approach involves trusting the vicinity of the offshore personnel to the measuring points because of their grounded knowledge of the site and the well. The same engineer continued as follows:

> [I]t is up to the data owners out in the asset because they know the formation, know they are supposed to hit this and that layer and so forth; they are fully responsible for the overall and the petro-physical quality of the data. And that requires a human to look at the screens and basically perform that type of checking.

Therefore, local experience of the site is a prerequisite for data validation. The same is true when an error is reported in an incoming dataset. Another OSC member echoed his colleague:

> [W]hen you have typically [Driller A] doing an MWD [measurement while drilling] and you have [Driller B] doing surface in the same rig, they are not doing the same depth references, so they are both wrong or both right. (...) But to really fix this problem, you have to really get closer to the sensors, to the system, and you have to really fix it offshore for every rig that is where you actually are solving it. And you need to monitor it and follow it up.

However, the OSC does not solely rely on the ability of offshore personnel to spot errors. Validation practices are also tied to economic incentives. The centre has developed a complex system of penalty and bonus contracts to either penalise or award service companies based on their capacity to provide trustworthy datasets. It is a flexible system because penalties or bonuses are directly proportional to the money that a service company earns for providing the datasets in each drilled section of a well. This approach is standardised because the OSC applies it to all of its service companies and it stems directly from the contract, regardless of the details of the subsurface sensors. In a nutshell, money is directly linked to the technical quality of the datasets by increasing the bonus (or the penalty) as the drill bit nears the reservoir. This system triggers the development of better measurements from the service companies and indirectly becomes a metric for measuring the datasets delivered.

A review of the existing *validating* strategies taught NorthOil's environmental experts that the situated knowledge of the data collection site should be simultaneously ensured (thus leveraging on the experience developed when *sensoring*) and pragmatically tied to the company's standards and economic parameters.

Abstracting

Even if data are technically sound, predicting the risk associated with oil and gas operations is often difficult. Abstractions are necessary to cook the datasets further into a format that makes the possible risk for the environmental resources detectable and visible to the oil and gas professionals in the control room. We present two NorthOil's solutions to abstract risk representations for static (coral reefs) and moving marine fauna (fish).

The coral risk matrix. At the intersection between the oil and gas business and the environmental domain, NorthOil adopted a coral risk assessment method engineered by a third-party environmental service company to predict the risk to coral reefs. One of the experts who designed the methodology summarised it as follows:

> [W]e can express some kind of a risk to the operation (…). [W]e combined a probability based on the current measurements, and we have established a consequence matrix where we give the different habitats a value. We implemented dispersion modelling into this, and when we combine it to this resource map, of course, we get a risk of conflict between discharges and the resources.

Because corals are static resources, surveyors traditionally identify and label them on a 2D map of the seafloor. The map is subsequently overlain with a prediction of the particle plume that is generated during a planned drilling operation. Each coral structure is then mapped onto a 'coral risk matrix', based on the vicinity of each coral structure to the particle plume (Figure 5). The risk matrix is an adaptation of a general-purpose risk visualisation tool that represents corals as risk objects. The probability for a coral structure to be hit by the discharge plume (likely, large, moderate, or small) is evaluated against the consequences that the discharged particles may have on that structure (i.e., if the coral is healthy, the consequences will be severe; if it is dead, the consequences will be minor). Boundary values are set for each specific case in collaboration between third-party experts and the Norwegian authorities.

The coral risk matrix is finally included in a standard list of attributes describing a coral structure and is used to archive and compare the results of different surveys. Because the coral risk assessment methodology has been adopted by the Norwegian Oil and Gas Association, the risk matrix has become an infrastructural element for operators who seek to locate safe drilling locations on the NCS.

		Consequence			
		Minor	Low	Considerable	Severe
Probability	Likely				
	Large				
	Moderate				
	Small				CR-01

Figure 5. The coral risk matrix (reproduction by the authors).

The environmental value. Assessing the risk associated with moving marine resources is not easy. A typical model for displaying the echo sounder measurements is the chromatogram, in which measurements are plotted over time and coloured in different ways based on the concentration of marine biomass at a given depth. A chromatogram for the area surrounding the Venus station was displayed on the Venus web portal (see Figure 3). In late 2013, a few members of the Venus project travelled to a small town in north Norway to present the Venus web portal to a local community of fishermen. Positive feedback was received. A local newspaper wrote enthusiastically that the portal was becoming "*More popular than the Disney Channel*" (Figure 6). However, the fishermen also noted that the chromatogram was too densely populated for their purposes. In addition, the chromatogram's granularity was deemed excessive by some environmental experts

Figure 6. Newspaper report on the workshop between NorthOil and the fishermen. Title: "More popular than the Disney Channel. Now you can see reality TV from the seafloor outside Bø. On Thursday, the ocean observatory of [NorthOil] and the Marine Research Institute was opened. It can also be useful for local fishermen" (Erlandsen, 2013, faces covered for anonymity).

who were collaborating with NorthOil because the users of the analysed environmental trends want to receive results on a monthly basis; their databases are not ready for such detailed datasets.

To overcome these difficulties, NorthOil and its partners took inspiration from the coral risk matrix. In so doing, they decided to synthesise the water column into a discrete set of values. Each of these values represented a biomass indicator that summarised the biomass concentration in larger chunks of the water column (Figure 3). The biomass indicator was then named an 'environmental value', inheriting an earlier term from the Norwegian Directorate for the Environment[1]. The environmental value is obtained by collapsing a subset of the original sections scanned by the echo sounders into one; measurements are provided at hourly intervals instead of every few seconds. This strategy enhanced not only the visualisation but also the storing of data streams, generating drastically fewer data entries every hour. As presented during a 6-hour project meeting with representatives from NorthOil and its partner companies, the environmental value has been defined by two participants as a

> [N]ewly cooked term… to express environmental happiness!

Upon closer inspection, the environmental value is the evolution of the risk matrix applied to moving marine biomass:

> [W]e want to do [the coral risk assessment] more generic, meaning that it can be used for other environmental resources as well (…) But you can also think of using the same method on the pelagic species like fish and things that swim around and move. (Environmental advisor)

However, adapting the coral risk assessment method to the fish revealed a hidden challenge: fish and marine biomass are continuously moving, meaning that the environmental value means different things at different moments and in different locations. For example, two fish in usually deserted areas represent a high concentration, whereas two fish in an otherwise densely populated location represent a low concentration. To collapse the unpredictability of nature into abstractions that work in an operational setting, the risk categories based on the environmental value must be calibrated with historical data, but such data are currently unavailable to NorthOil. In sum, *abstracting* mechanisms feed back into the *sensoring* and *validating* practices, which, in turn, shape the abstractions of the marine environment.

Infrastructuring the sea into a baseline: Seeking environmental happiness?

The fish quoted in the beginning sounds very annoyed. It repeatedly pops out of its coral shelter to *speak* to the camera. Is it really annoyed, after all? Or is it attracted to the camera? Our research question could be rephrased as follows: *How does 'Shshshshsh!' come to mean something for NorthOil in its long-term efforts to gain permission to operate in Venus?* The infrastructuring mechanisms that we have outlined serve to stage the voice of the fish as part of a measurable and repeatable play in NorthOil's world (cf. Mol, 2002). NorthOil crafts a baseline *despite* limitations in the time-space sampling of data and the profound uncertainties surrounding the possibility of gaining robust knowledge to feed risk assessment practices.

We build upon the literature reviewed above to convey the key message of this paper. First, "raw data should be cooked with care" (Bowker, 2005). The fish's voice is heard – or 'cooked' – through specific sensor configurations (*sensoring*) and processes to assess the incoming data as trustworthy (*validating*) and understandable (*abstracting*). Second, not only one hydrophone, but also an entire knowledge infrastructure is needed to translate the voice of the fish into a trend of the environmental behaviour of that portion of Venus. This process seeks to quantify the little knowledge that we have about a small submarine area into representations of ecosystem behaviour and embed them into the operations of a globally distributed oil and gas company.

NorthOil's case exposes the new infrastructural relations while they are accommodated at the boundary between the existing, operation-based routine monitoring and the new possibilities afforded by a new space such as Venus. The emerging tensions between oil and gas corporate processes and environmental (non-)knowledge cannot be solved because of the incommensurable nature of large-scale industry and the environment; whereas the first is tied to predictable and routinized work processes to ensure its productivity, the latter does not fit well into this type of system. As the environmental chemist quoted above commented, "*no environment is constantly… constant over the whole time*". We observe NorthOil's deployment of trust-building techniques to purposefully manage this unsolvable controversy and to mould the political dimension where the company is operating.

Three dimensions emerge from comparing our findings with those of the literature presented above: space, time, and trust. Our case is novel because NorthOil is simultaneously changing the context and the machinery of data production and curation along these three dimensions through an infrastructural inversion.

Infrastructuring space and time

The purpose of embarking on environmental risk monitoring is to create a 'global' account in the sense that one assesses not only the specific measurements that are actually collected but also the risk of extended regions/areas or habitats (cf. Power, 1999). This purpose thus assumes quantification to allow local measurements to travel and involves grappling with certain tensions that we discuss here (Porter, 1996).

First, a spatial connection exists between the working method and the perspective that we have on certain phenomena (Edwards, 2010). Similar to Almklov and Hepsø (2011), although the drilling process necessarily occurs from the top of the well, the OSC must make sense of the online data stream from the bottom up. The same applies to the acoustic sensors deployed in Venus. Having originally been used on floating vessels, they are now turned upside down and made stationary, residing on the seabed. The data remain the same; however, the altered spatial perspective (from the bottom, not the top) simultaneously renders them different. Reversing these spatial orders also emphasises the material dynamics involved in measurements. Acoustic signals collected at the bottom exhibit different reflections when they encounter a fish's swim bladder. Global knowledge is made possible locally (Latour, 1999). When knowledge infrastructures are designed, this aspect must be carefully taken into account for its political meaning: the material relations between the infrastructure and the outside environment (e.g., sensors/swim bladders), if properly handled, have the potential to shape how risk is perceived outside (e.g., through the environmental value).

NorthOil's infrastructuring mechanisms have a generative potential in how they allow for the purposeful management of the interplay between global access to data and knowledge of the local processes of data acquisition (cf. Zimmerman, 2008). For example, the Venus project participants had to learn how the echo sounders functioned with respect to the swim bladder of some fish in the Venus area. The OSC bonus/penalty contracts must be complemented by the experiences of offshore service companies related to subsea formations. At a first glance, the coral risk matrix represents an outstanding exemplar of the creation of a contextual void. Such a simplified representation is also useful for comparing different environmental surveys in a particular area at different moments. As the world is reduced to inscriptions through measurements and simplifications ("*we give the different habitats a value*"), local knowledge can be amplified ("*we can express some kind of risk to the operation*"). However, under scrutiny, the risk matrix does not exist in a vacuum. It embeds locally acquired expertise to assess what is a healthy coral reef and the experience needed to define a safe distance from a drilling location. However, the strategies for tackling the local/global interface and achieving baseline environmental data might follow different dynamics if we consider other types of risk, such as climate change risks. In that case, risk calculations are primarily (but not entirely) performed at global scales, for example through climate models that are then adapted to the local setting (Edwards, 1999, 2010). In the case of subsea environmental monitoring, the opposite is generally true: representations such as the environmental value, are made 'global' but remain grounded in the historical data gathered at the local site.

Second, NorthOil's efforts are ostensibly about creating a knowledge infrastructure for *real-time* data. What used to be an offline, disconnected, and slow practice in which risk was often assessed in an ex-post manner has suddenly become fast, interconnected, and closely visible. This shift occurs by balancing the years during which the environmental trends become clear and the seconds that the technology uses to measure them. Different conceptions of time must be frozen into different enactments of risk that make sense to the different stakeholders that are involved. However, a variety of incommensurable time scales exists, all of which are imbricated with distinct materiality (Ribes & Finholt, 2009; Steinhardt & Jackson, 2014). The starting point is a system such as the bonus/penalty contract used by the OSC. The formulation of this contract enacts risk as an economic risk for the service company. If we unpack the contract, it is a compromise between the months and years required by formal governance and the seconds with which drilling engineers operate. Similarly, the enforcement of the risk matrix by the Oil and Gas Association led it to acquire an infrastructural quality that intersects the oil and gas and environmental domains. It represents a trade-off between the temporality of risk to the coral reefs (damage might become visible over the course of several decades) and what constitutes risk to operations (being stopped, which is visible in only a few seconds). In extending the matrix, the environmental value was developed by adding one step not only to create real-time monitoring machinery but also to make it dynamic. Because no operations are currently permitted in the Venus region, the environmental value constitutes an indirect measure of risk and computes in a few seconds the historically relative amount of marine fauna that could potentially be affected.

This new real-time/long-term scenario introduces new ways of assessing the risk associated with present or future oil and gas activities. As a consequence, it dramatically shuffles and ultimately reduces the temporal gap between human operations and their possible consequences. In analysing how risk emerges as a phenomenon, we should be specific about the agency of the material elements because, if the feedback loop between an action and its consequences is shortened, the generative role of the combined materiality of nature and technology gives birth to new and unprecedented results.

Trust infrastructuring

We suggest that future STS research could pay more attention to the way infrastructures are "constructed as a public problem in specific imaginative spaces of opportunity and closure" (Schick & Winthereik, 2013: 82; Jirotka et al., 2005). Infrastructures always inscribe a political address in the way technologies are configured to represent specific possibilities of modernity and future (Larkin, 2013). Barker (2005) describes how that happened in Indonesia, where satellite technology was infrastructural to build a sense of national self in the country through the daily work of engineers. NorthOil's strong but contested political-economic position in the Norwegian context led the company to invest in becoming infrastructural to the construction of environmental risk in Venus as a public problem for specific audiences. The infrastructuring mechanisms described above are thus complemented by a subtle but continuous application of techniques of social networking and openness – a combination that is not often registered in the infrastructure literature. Interestingly, these strategies are directed towards building *trust rather than consensus* with the potential stakeholders of NorthOil's infrastructure, including fishermen, research institutions, and the general public (Shapin & Schaffer, 1985; Yearley, 2009). In other words, NorthOil is opening a space of mutual respect about the means for rather than the ends of real-time environmental monitoring. For example, the a priori antagonistic relationship between fisheries, the environment, and petroleum operations has not and most likely will not result in a consensus. Instead of a stand-off awaiting consensus, "[in] the presence of antagonism…decisions often have to be arrived at…in the face of persistent disagreement" (Barry, 2013: 7).

Bowker (1994) highlights the importance of building an onshore 'social infrastructure' that mirrors the technical subsea infrastructure. Let us consider two public risk representations developed within the Venus project: the chromatogram and the environmental value. They are associated with NorthOil's careful work of *social* *infrastructuring* around the specific problem of subsea environmental risk, for which no closure has been reached in public debates. This aspect shows how the relationship between data and data *perception* is inextricably connected to mutual trust (Yearley, 2009: 158). Conveying the message that the Venus web portal – used to display the environmental value and the chromatogram in real time – is better than the Disney Channel lessens the tensions generated by everything related to oil and gas – not only with the fishermen to whom the presentation was addressed but also with the newspaper readers. This message resonates with the definition of environmental value as a "*measure of environmental happiness*". This mechanism also occurs in the context of the more traditional drilling operations, where measurements are often conducted by one or more service companies. Incomprehension happens when the OSC lacks a reference to service company measurements and when "*they are not doing the same depth references, so they are both wrong or both right*". To quote the OSC engineer, "*if you don't trust the data, you don't use the data, and some shit happens*". It is true that "the ability to comprehend data collected by others…is the key to their use" (Zimmerman, 2008: 648), but trusting how third parties perform the work (rather than why) is a necessary condition for trusting the data that they produce (Borgman et al., 2012). What differs in Venus is that measurements are collected in a non-operational area, where no direct oil and gas interests can be claimed. This aspect underlines the second relevant feature of NorthOil's trust infrastructuring mechanisms: openness. The Venus real-time data are shared through a colourful publicly accessible web portal. On the one hand, the absence of operational data and the openness of the portal enforce the genuine impression of the Venus project and shadow its business-related character. On the other hand, given how little we know about the Arctic sea floor, these features are a strategy to enrol collaboration from external research institutions that might not agree with NorthOil's motivations, but crave datasets to develop a better knowledge of the marine ecosystem.

NorthOil's approach to building trust shows that infrastructural inversion has an economic thrust. Some within NorthOil argue that openness is in particular a prerequisite for achieving credibility, including in cases of legal liabilities, with governmental agencies. However, one of our informants noted that the current strategy of openness might be discouraged when/if the uncertainty about the environment is quantified into measurable economic concerns:

> There is not so much profit involved [in environmental data]. For the moment!

Conclusions: The politics of risk

We probably still know the moon better than we know the seabed. We reported on NorthOil's strategies to overcome this status of non-knowledge in the Arctic marine environment and to establish a baseline of the marine ecosystem behaviour to assess operational risk. We followed the data construction process across a knowledge infrastructure-in-the-making and analysed how uncertainty about the marine environment is quantified into a knowledge base by carefully leveraging cross-infrastructure spatial, temporal, and socio-political tensions. Infrastructur*ing* highlights the continuous, interacting, and distributed nature of NorthOil's efforts in an amalgam of design, development, and adaptation work. To support its infrastructuring strategy, NorthOil is investing in building a context of mutual trust, rather than consensus, with external stakeholders. Our case complements the infrastructure literature by showing that infrastructural inversion also consists of tuning strategies of social networking and open data sharing and, as such, has a key role in establishing trust. This observation invites us to reflect on the politically charged character of 'facts,' technologies, and numbers (Barry, 2013; Bowker, 2000). What can we make of the way in which the politics of risk unfold between the oil and gas world and environmental concerns?

First, there are not only profound uncertainties about environmental knowledge as we have described it: there are also ambiguities about what constitutes oil 'operations' and their consequences. The international newspaper The Guardian has initiated a campaign against providing financial support to companies that operate using fossil fuels[2]. The Venus area is presently off limits to oil drilling and production; however, the area is subject to seismic 'surveys.' Seismic surveys are conducted by shooting bursts of seismic sound-waves from long cables trailing vessels that are directed towards the seabed and then reading off the echoes. As environmentalists have noted, these surveys are likely to be harmful to whales and other sea life, although nobody knows to what extent. One marine biologist, quoted in a Norwegian newspaper (Vegstein, 2014), uses hydrophones to listen to the singing of sperm whales in the vicinity of Lofoten. She then detects the seismics from the ongoing "surveying". Through the hydrophones, the seismics sound like "thunder" or "explosions" and cause the whales' singing to subside:

> They tell us Lofoten is sheltered from oil operations. That is political bollocks. This ocean is severely affected. It is only that we cannot hear it [without hydrophones].

Second, it is not clear whether other oil and gas companies are interested in bringing possibilities for online and open environmental monitoring to the attention of the authorities. Traditionally, the operators have taken more of a back seat role. One of our informants told us that other operators were contacted about environmental monitoring initiatives, but they withdrew as they feared that they might be required to pay for and install new technologies. This point hides an important conception of the relation between infrastructure and power. NorthOil has larger competitors in the quest for subsurface resources in the Arctic, with stronger economic and political weight. Investing in similar technological innovation strategies would probably make less sense for them. NorthOil's infrastructuring mechanisms are weaved into the Norwegian context (e.g., the co-presence of a strong fishery infrastructure) and NorthOil's size. For NorthOil and its stakeholders to survive, it is important to sit where a specific future (e.g., real-time environmental monitoring) is being constructed thus where uncertainty is turned into a knowledge base.

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Notes

1 See 'Environmental values in Norwegian marine areas' (http://www.havmiljø.no/) for additional details.

2 See http://www.theguardian.com/environment/series/keep-it-in-the-ground

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Outbreaks and the management of 'second-order friction': Repurposing materials and data from the health care and food systems for public health surveillance

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Abstract

In the US, the public health system plays a key role in identifying unsafe food in the food supply. This identification work (public health surveillance) entails piecing together and reworking materials and data from the health care and food sectors to identify the ultimate cause of the problem. As such, the public health system depends heavily on infrastructures built for other purposes to achieve its goals. Using the case of foodborne outbreak detection, this article enhances the ethnographic analysis of second-order systems by incorporating the concepts of 'repurposing' and 'friction' to analyze this dependent relationship, the challenges it entails, and the broader sociopolitical and ethical consequences of connecting heterogeneous infrastructures. I examine how actors within the second-order system of public health conduct the practical work of repurposing materials and data from other sectors, and grapple with the inescapable presence of 'second-order friction' between their system and infrastructures built to achieve other goals.

Keywords: second-order friction, repurposing, foodborne disease outbreak surveillance

Introduction

Food supply chains are highly complex. They rely upon a large and diffuse network of interdependent infrastructures to get food from farm to fork, and align producer supply with consumer demand. If food becomes contaminated somewhere along the way, often the problem only gets discerned much after the fact, when an outbreak occurs. The visible signal that something has gone wrong is when end consumers get sick and seek medical care. However, the job of the health care system is to treat patients, and so it focuses its efforts on fulfilling that function. In the US, going as far as identifying the food that made the consumers sick is not part of its responsibility, and so the health care system only collects information relevant to fulfilling its clinical function. Figuring out what food caused the problem is the responsibility of the public health system, which must piece together and rework materials and data from the health care and food systems to identify the ultimate source of the outbreak, and help ensure the safety of the food supply.

To be efficacious, outbreak surveillance depends on robust linkages between the disparate sectors of public health, health care, and food production. Scholars have theorized systems that depend heavily on infrastructures built for other purposes as 'second-order systems' (Braun & Joerges, 1994; Van der Vleuten, 2004). Second-order systems refer to "the process of networking parts of different first-order systems for specific, macro-level social domains" (Braun & Joerges, 1994: 27). Braun and Joerges developed the concept in their study of a European organ transplantation network. This cross-national network depended on the interlinking of a variety of existing infrastructures ('first-order systems'), such as road and air transportation, telephony, long-distance data transmission, and hospitals, to achieve the goal of getting organs from donors to recipients in an expedient fashion. The concept of a second-order system has been used to look at the macro-level structural/functional aspects of these kinds of systems and how they develop over time. Complex adaptive systems scholars have studied the interdependencies of infrastructures using modeling and simulation to understand system vulnerabilities and the implications of rare or extreme events (Rinaldi et al., 2001). What is not addressed in these research traditions are two important aspects to infrastructural interdependency: the daily practical work of actors who create and maintain dependent systems, and the sociopolitical and ethical consequences of connecting heterogeneous infrastructures.

This article enhances the ethnographic analysis of second-order systems, bringing both practical work and its broader consequences to the foreground by introducing additional analytic language for understanding multi-infrastructural dynamics. As Vertesi (2014) argues, we need more vocabulary for understanding how actors skillfully work to bring multiple infrastructures into alignment, and work around given constraints and limitations. Using the concepts of 'repurposing' and 'friction,' this article helps surface some of the 'invisible work' (Star, 1999) involved in making infrastructures built for other purposes serve public health needs, and connect that invisible work to its larger sociopolitical and ethical consequences.

Second-order systems rely heavily on infrastructures built for other uses, and actors within those systems encounter multiple challenges in their work because of their system's dependent relationship. I argue that the concepts of 'repurposing' and 'friction' help us more deeply understand this dependent relationship and the challenges it entails. 'Repurposing' is the adaptation of things that were created for one purpose to be used in a different way. As actors within second-order systems conduct the practical work of repurposing materials and data from other systems, they grapple with the inescapable presence of 'second-order friction,' or resistive force, between their system and infrastructures that were built to achieve other goals.

Surfacing the invisible work of repurposing and its sociopolitical and ethical dimensions is especially important for understanding public health. Public health practitioners often lament that public health is invisible when it works, because people are not getting sick. This invisibility contributes to the neglect of public health infrastructure, and ultimately, the health of populations. Using the concepts of repurposing and second-order friction, I tack back and forth between the practical work of maintaining second-order systems, and the sociopolitical and ethical consequences of that work, as a form of 'infrastructural inversion,' to better appreciate the "depths of interdependence of technical networks and standards on the one hand and the real work of politics and knowledge production on the other" (Bowker & Star, 2000: 34). This article describes and explains how public health actors responsible for foodborne outbreak surveillance repurpose materials and data from the health care and food sectors to achieve system goals.

I draw empirical material from a larger three-year project that examined the evolution of foodborne outbreak surveillance systems from a historical and ethnographic perspective. That project used a 'strategically-situated' approach, sampling key sites within the larger distributed system where participants were themselves managing questions of scale and distribution (Geiger & Ribes, 2011). My understanding of the system's broad contours came from six months of organizational ethnography at the Centers for Disease Control and Prevention (CDC), and four months of regulatory work at the Food and Drug Administration (FDA). My look at the system from a more local perspective draws largely from a week-long site visit at a state public health department and laboratory that involved observation of work practices and interviews with staff. It was there that I was able to get a closer look at how public health practitioners managed the daily work of repurposing materials and data, and the frictions they worked to overcome. To deepen the analysis, I also draw selectively from other data sources, including one-on-one interviews with state and federal public health and regulatory scientists, policy documents, field notes from scientific meetings, and relevant scientific articles and media stories. For data analysis and theory construction, I used an abductive analysis process to seek a "situational fit" between my ethnographic observations of outbreak-related work and STS theory (Timmermans & Tavory, 2012). Abductive analysis led me to the large technical systems and knowledge infrastructures literatures, which informed the development of the second-order friction concept.

Because my approach is strategically-situated, it is limited by its partial view. It emphasizes the vantage point of the second-order system, which is built and operated by public health scientists. Observing the interactions between the system and existing infrastructures from other locales would reflect different facets of repurposing and friction, highlighting instead the concerns of the builders and operators of other infrastructures. Another limitation of the study is that I looked at only one state public health department and laboratory, when there is significant variation between states (e.g. funding, population size, degree of centralization). I do not capture differences between states in this study. However, the examples of repurposing and friction I discuss reflect more general challenges faced by many public health practitioners in this second-order system.

The remainder of the article proceeds as follows. In the next section, I develop a conceptual framework and situate it in the STS literature. After that I examine second-order friction from a broad, structural vantage point. Then I take a more local look at the practical work of repurposing and actors' management of frictions in day-to-day public health surveillance. Before concluding the article, I look at the friction associated with second-order adaptation to change in other infrastructures.

Conceptual framework and literature review

The concept of a second-order system comes out of the large technical system field inspired by Hughes (1983, 1987). Since Braun & Joerges' (1994) pioneering study, Van der Vleuten (2003) has built upon the second-order system idea through an analysis of the Dutch food supply chain. Second-order systems have three overarching properties. They are:

1. *Parasitic*. Second-order systems opportunistically borrow from other systems and infrastructures to achieve their goals, and tend to maintain less of their own substance. There are several advantages to a parasitic structure. It may be too costly, infeasible, or even impossible to create a contained system with dedicated infrastructure. The latter is true for both organ transplantation and disease outbreaks, in that they both involve unpredictable accidents at their source. Since donors or illnesses can come from anywhere at any time, second-order system builders must mobilize existing infrastructures to support their efforts.

2. *Reliant on databases*. Though second-order systems may maintain less of their own substance, they still require dedicated infrastructure. Databases often serve as key components of second-order systems, because they are powerful tools for coordinating spatially distributed, multi-scalar, temporally-complex phenomena. They help provide foci for drawing natural, social, and digital orderings together (Hine, 2006).

3. *Dependent*. While there are many advantages to second-order systems' parasitic structure, there can be significant disadvantages. Because they draw substance from heterogeneous infrastructures, they tend to be less "insulated" from malfunctions and changes in other systems (Braun & Joerges, 1994). Second-order system builders have multiple aspects of their system that are not under their control, resulting in an 'asymmetrical dependence' (Van der Vleuten, 2003; Mayntz, 1993). This is why questions of power are so relevant to understanding the relationships between second-order systems and existing infrastructures.

The second-order system concept is an analytic tool that helps analysts examine systems reliant on the interconnection of multiple infrastructures. In my view the concept is best applied to situations where readily identifiable second-order system builders actively work to mobilize multiple infrastructures in service of achieving a clearly defined goal. Navigating any complex contemporary environment involves working in and between systems and with multiple infrastructures, and produces "fleeting moments of alignment," but not necessarily a stable whole (Vertesi, 2014). By contrast, second-order systems must regularize alignment to achieve system goals. This is a challenge because absolute stability is not possible because of a parasitic structure with many disparate elements not under second-order system builders' control. As such, second-order systems are best seen as unstable wholes, made stable enough by the practical work of actors committed to keeping disparate infrastructures aligned.

Given the key role that the practical work of actors plays in holding second-order systems together, it is important to develop conceptual ways of describing and analyzing this work. The concept of repurposing is a particularly good one to analyze the work of holding second-order systems together, because it calls attention to the original and new purpose and context of development, as well as their interaction effects. The general idea of repurposing has a long history in STS, but only recently have scholars refined it into a more specific analytic concept.

That different social groups can have different uses and meanings for the same objects and artefacts is a well-established STS principle. The Social Construction of Technology (SCOT) approach (Pinch & Bijker, 1984; Kline & Pinch, 1996) emphasized that users were an important social group playing a role in technology construction, and highlighted the interpretive flexibility around the different meanings different social groups ascribed to a technology. Star & Griesemer's (1989) influential concept of the boundary object captured how actors in different but intersecting social worlds could coordinate cooperative work without coming to consensus. Domestication theory (Lie & Sørensen, 1996; Silverstone & Hirsch, 2003) called attention to the integration of technologies in everyday life, involving the reshaping of technologies and user meanings and identities in the process. Dourish (2003) called the process of adopting, adapting, and incorporating technologies into working practices 'appropriation,' seeking to discover features of technical design that could fruitfully support it. Data 'reuse,' or data that was collected for one purpose being used to study a new problem, is an analogous phenomenon (Zimmerman, 2008).

In contrast to earlier work that focused on individual technological artifacts or a single system, scholars have more recently elaborated the concept of repurposing to better appreciate the dynamic relationships between heterogeneous infrastructures and multiple systems. Jarzabkowski & Pinch (2013) have called for a focus on repurposing as one of the key concepts to advance further empirical studies of sociomateriality. They argue that prior studies have tended to focus on affordances and new functions and intentions for objects. Instead, scholars should examine the situated activities actors accomplish in repurposing objects in context, and the social interactions between groups involved in purposing and repurposing things. Jackson (2014) has pointed to activities like repurposing as important phenomena to investigate understudied technological dimensions such as repair, maintenance, breakdown, and decay, instead of the more attention-getting novelty, growth, and progress. Repurposing offers us new ways to think about innovation and inequalities involved in social relationships around technologies. Ribes & Polk (2015) highlight the importance of repurposing to maintain long-term research endeavors and enable the investigation of new research objects. Importantly, they point out, repurposing requires effort to ensure that infrastructure can facilitate research on new objects of investigation without disruption.

When considering the dynamic relationships between different infrastructures and different social groups involved in aligning and repurposing materials and data, it is important to have ways of talking about how actors enact and experience those relationships. Tsing (2005: 4) theorizes friction as the "awkward, unequal, unstable, and creative qualities of interconnection across difference." It is the force resisting the motion of moving surfaces in contact, and requires significant energy and effort to overcome. Tsing uses friction to tack back and forth between scales, interrogating the production of the global and local, universal and particular, and the constitutive relationships between them. Also, she finds that encounters across difference do not just entail challenges for those involved, but can also stimulate creative possibilities and the development of new cultural forms.

Edwards (2010) and Edwards et al. (2011) have taken a typological perspective to theorizing friction in knowledge infrastructures, to explore the challenges associated with different aspects of knowledge production. Actors in knowledge infrastructures must commit time, energy, attention, and resources to overcome many resistive forces. What the concept of friction usefully does in this arena is to emphasize the materiality of information, which is often framed as immaterial. 'Data friction' results when data must move between people, substrates, organizations, or machines, and in the work required to collect, check, store, move, receive, and access it. 'Computational friction' is associated with the work required to process data and turn it into information and knowledge. 'Metadata friction' arises with the work involved in managing and communicating information about data, important for making it shareable in multi-disciplinary, collaborative efforts. 'Science friction' refers to the challenges encountered by different scientific disciplines when they work together on related problems.

This article tracks the 'second-order friction' that results when actors in the second-order system repurpose materials and data from other systems and infrastructures. In that repurposing work, they encounter frictions of many forms. To understand foodborne disease outbreak surveillance, it is useful to consider second-order friction at multiple scales, tacking back and forth between the broad structural aspects of connecting health care, public health, and food production systems, and the intricate work of repurposing materials and data at a more local level. It is also important to connect the practical work of repurposing to its broader social context. Indeed, managing daily second-order frictions can make the political and ethical consequences of foodborne outbreak surveillance seem distant to the actors doing it. Yet those political and ethical consequences are what provide the work with larger meaning and moral purpose—making the food supply safer. As one interviewee told me during my site visit, "It can get hard to 'see the forest for the trees' in day-to-day surveillance. We take a 'fire engine' response to problems, but we can lose the bigger picture."[1] The interviewee used the forest-trees idiomatic expression to emphasize how difficult public health workers found it to discern broader patterns when overwhelmed by the details of their daily work. In addition, the emergency-response 'fire engine' mode of work presented another challenge in feeling connected to the work's broader political and ethical implications.

Second-order friction from the forest

The specific second-order system examined here is a foodborne outbreak surveillance system. However, I emphasize that it is layered in multiple ways. At the micro-layer, the system can be defined in terms of specific tools, such as the surveillance database. At the meso-layer, it is important to consider how foodborne outbreak surveillance is housed within the larger public health system, so that issues such as state-federal relationships come into play. At the macro-layer, a broad system goal for outbreak surveillance is to network the first-order systems of health care and food production, to identify the ultimate cause of food contamination.

Foodborne outbreak surveillance is one of many types of public health surveillance, which Thacker & Berkelman (1988) define as the ongoing systematic collection, analysis, and interpretation of health data, integrated with data dissemination and application to programs for prevention and control. This epidemiologic monitoring of patterns of disease at a population level is a function typically conducted by government entities, who are responsible for official disease reporting. In the US context, the idea of disease reporting dates back to the 18th century and concerns about potential epidemics of communicable diseases such as cholera, yellow fever, and smallpox. The national system in place today began to take shape in the last few decades of the 19th century, growing out of late 18th century developments, such as sanitary reform movements and the rise of municipal and state boards of health as governing bodies (Fairchild et al., 2007; Koo & Wetterhall, 1996; Duffy, 1990).

Because government bodies are responsible for producing official statistics about the health of the nation, significant resources and effort must be put into transforming data from disparate sources not originally intended for public health use, into trustworthy numbers that have public health meaning. Public health surveillance systems often repurpose data from a variety of sources, such as "clinical laboratory test results, patient encounter data, environmental monitoring, pharmaceutical sales data, insurance claims data, vaccination registries, vital statistics, morbidity and mortality data, and notifiable disease reports" (Mirhaji, 2009). One of the primary sources of data for many public health surveillance systems is the health care sector. The parasitic relationship of the public health sector to the health care sector is formalized by disease reporting laws made by state legislatures, which require health care professionals to report diseases of public health concern to the government.

By their own rights, the American public health and health care systems are each large, complex, fragmented, and highly regulated, which makes the task of connecting the two all the more challenging. One of the most significant sources of friction in the public health system is the balance of power in America's federalist system. Some states have given local (county and city) governments little authority to govern public health, while other states (deemed "home rule") give local authorities more control. While states are the primary entity responsible for health in the public sector, the federal government is responsible for coordinating the dissemination of knowledge and policy-making, priority-setting, and providing technical assistance and resources for strengthening state and local capacity (Institute of Medicine, 1988). An outgrowth of this complex distribution of power is a complex distribution of responsibility for collecting and managing data and materials.

The structure of the health care system causes friction for patients and caregivers. They must navigate a pluralistic delivery system comprised of large numbers of small providers in different kinds of venues, such as primary care facilities, specialty clinics, and diagnostic centers, and in any one facility, a single patient may be cared for by a physician, nurse, pharmacists, medical assistant, or other caregiver (Bodenheimer, 2008). In this context, a patient's medical record is not a simple object that can easily travel. The medical record is a complex infrastructural entity comprised of numerous written and digital traces mediating the production of the patient's body, the hospital as an organization, and wider connections to multiple bodies politic (Berg & Bowker, 1997). Though many clinical environments make use of information systems to produce electronic medical records more efficiently, it is important to understand that the data are produced and used in the context of direct clinical care. Even repurposing data for in-unit clinical process improvement presents a number of challenges (Morrison et al., 2013), let alone repurposing this data for public health use.

To touch on the making of the medical record in the foodborne context, whether an illness is a foodborne one or not is unclear at the outset, when a person first gets sick and seeks medical care. Both the clinic and the laboratory are involved in evaluating individuals that present symptoms of gastroenteritis. Clinicians perform differential diagnosis by analyzing various aspects of the patient's symptoms. For example, timing of the onset of symptoms suggest infection from different pathogens (Donnenberg & Narayanan, 2013). If a person gets sick within 6 hours of ingesting a problem food, *Staphylococcus aureus* is more likely to be the cause. If onset of symptoms is between 6 and 48 hours, some of the possible causes are *Shigella*, *Salmonella*, or *Escherichia coli*.

Making sense of different clinical symptoms can help direct the laboratory to perform the right kinds of tests that will identify the infectious agent from a patient's biological sample (normally stool). The particular clinical diagnostic test that can be repurposed by the public health system is the stool culture, which involves taking a stool sample from a patient, and placing it in a special medium that encourages particular kinds of bacteria to grow, based on different phenotypic characteristics of different organisms. After the bacterial cells are grown in a selective medium ("cultured"), laboratory technicians segregate the pathogen of interest; that is, they separate a pure variety of a single pathogen from other bacteria. This step is always necessary because in the human body and in the broader environment, microbes exist in multi-member communities. The segregated pathogen is commonly referred to as an "isolate."

Second-order friction is associated with getting and repurposing the isolate and clinical data from both the clinic and the laboratory to the public health system. Clinical data and laboratory materials and data are often reported through separate channels and at different times. Public health practitioners must winnow down clinical data to repurpose it, for instrumental and legal reasons. From an instrumental perspective, only a small subset of data from the larger medical record is of interest for public health surveillance (for example, a patient's name, address, phone number, date of birth, gender, diagnosis, and symptom onset date). From a legal perspective, particular precaution must be taken in the handling of patient "protected health information" (PHI), governed by the Health Insurance Portability and Accountability Act (HIPAA), federal regulation to protect the privacy and confidentiality of individuals' medical records. Since counties and states are primary entities responsible for health in the public health system, fuller patient records containing PHI tend to be housed at the state level, and only linked to the federal level through de-identified codes.

Clinical data must be winnowed down, but clinical laboratory data are not sufficient for informing outbreak detection, and must be deepened for public health use. For outbreak detection, it is not enough to know whether the bacteria is a *Shigella* or *Staphylococcus aureus*. The isolate must be sent to public health laboratories to generate more specific data about its type, so that public health officials can determine whether an outbreak has occurred. Since the mid-1990s, state public health laboratories have been performing standardized molecular subtyping on foodborne isolates using a DNA fingerprinting method, pulsed-field gel electrophoresis (PFGE). When bacteria share PFGE fingerprints, this suggests that they might be members of the same outbreak, and initiates an investigation.

To manage the frictions of coordinating heterogeneous materials and data in foodborne disease outbreak surveillance, databases are key tools in the second-order system. On the laboratory side, from the early 2000s onward, state public health laboratories have been contributing PFGE data in PulseNet, a network and database for early-warning foodborne outbreak detection coordinated by the CDC (Swaminathan et al., 2001; Tauxe, 2006). PulseNet relies on commercial software for analysis of biological data, with customized scripts for data entry, queries, and submission of data to the national level (Gerner-Smidt et al., 2006). To facilitate collaboration and data sharing around national outbreak investigations, the OutbreakNet epidemiologic network of federal, state, and local public health officials uses off-the-shelf web-based platforms to support their investigative work (MacDonald, 2012).

While repurposing a patient's medical record and isolate entails connecting the health care system to the public health system, to help identify the contaminated food that is the source of an outbreak entails connecting the public health system to the food system. The food system is inordinately complex; Sobal et al. (1998) have conceptualized it as the "food and nutrition system" to account for its various subsystems (producer, consumer, and nutrition) and multiple stages (production, processing, distribution, acquisition, preparation, consumption, digestion, transport, and metabolism.) In contrast to the relatively more stable linkage between clinical laboratories and public health laboratories required for isolate shipping, the connections between the public health system and the food system are made in the context of specific outbreak investigations on an ad-hoc basis. However, what is stable is a key mediating actor between the public health system and the food system—state food safety regulatory agencies. Across states, food safety regulatory authorities can alternatively reside in departments of agriculture, food protection, and/or environmental health (Council to Improve Foodborne Outbreak Response, 2009).

Foodborne outbreak investigations rely on a method of epidemiologic case interviewing to collect "food histories" from sickened individuals. Once the health care system reports patient data to the public health system, public health staff contact cases to ask them questions about the foods they consumed in their homes, in the homes of friends and family, in restaurants and other food establishments, within the relevant disease incubation period, or time between exposure and illness (MacDonald, 2012). Who conducts food history interviewing varies significantly by state. In some states, particularly those under home rule, food history interviews are conducted by county public health nurses, while in others they are conducted by epidemiologists in county or state departments of public health. These interviews help generate public health practitioners generate hypotheses about the potential foods that may have caused a case's illness.

To figure out which food caused the outbreak, more evidence from the food supply and distribution chain must be collected to legally implicate it so it can be removed from interstate commerce and stop making people sick. Regulatory officials have jurisdiction over commercial data. They use a methodology called 'traceback' to figure out how food moved through the supply and distribution chain by collecting food records (National Environmental Health Association, n.d.). They begin at the endpoint of consumption, the transaction between a point of service and the consumer, and obtain distribution records to identify shipments and suppliers back through the chain until a common source is found, an outcome they call convergence. Officials seek data from cases and points of service such as purchase date and location, brands and descriptions of food items, packaging and labeling information, and lot numbers. They also ask those points of service for lists of suppliers, delivery information, shipping documents such as invoices and bills of lading, and inventory records. Ultimately, officials aim to find the common source at the production or farm-level, to identify what caused the contamination issue. Supply chains are designed to get food from producers to consumers, so in repurposing food records to trace a food's journey from consumer to producer, regulatory officials encounter significant second-order friction.

Second-order friction from the trees

"Outbreaks have been pushing communication and community," a technician observed. From this technician and many of the other public health scientists I interviewed, I repeatedly heard an emphasis of the importance of relationship-building across distributed organizations. Collegiality was an important element smoothing the friction of coordinating work and sharing objects and data between heterogeneous and dispersed groups. Previously, the technician stated, before the frequent detection of outbreaks, "state laboratory people didn't meet their epis and ag [state department of agriculture]." Since its inception, a significant amount of PFGE data has been accumulated in the PulseNet database, resulting in the increasingly frequent detection of possible outbreaks; in this laboratory technician's state alone, the state public health laboratory subtypes between 900–1,100 *Salmonella* isolates a year.

At first much of the coordination and communication were organized by phone calls and e-mails, but eventually the two groups decided that the epidemiologists should also have access to the PulseNet database, normally a tool managed by the laboratory. This repurposing of a national laboratory database as a local laboratory-epidemiology communication tool helped to facilitate better coordination between the two teams. More specifically, it helped the epidemiologists keep closer tabs on incoming information about isolates of interest.

However, giving the epidemiologists access to the PulseNet database did not entail a complete repurposing of the tool as a space for conducting epidemiologic data analysis. During the site visit, much of the daily work I observed foodborne epidemiologists conducting was in a database I call EDSS, for Electronic Disease Surveillance System. EDSS was a shared resource across the whole department of public health since it was a cross-disease database system for all reportable diseases. I found out that as a shared resource, it was a site of friction resulting from tensions between the surveillance needs for different diseases. A technical limitation of EDSS was that it was a standardized product created by a commercial vendor, and as such, the data fields it contained had to be common across disease domains. Customization was expensive, an epidemiologist informed me; "every change is dollars."[2]

Besides generic data fields, another challenge was that it was difficult to extract data from EDSS. The epidemiologist continued, "The system was built for putting in data, but in our line of work, we want it out. How do we search it?" Even though EDSS was ostensibly built for putting in data, observing the friction associated with this process revealed the human work required to repurpose data from the health care system. Several times a week, an epidemiologist would update EDSS with foodborne case data. Updating EDSS involved an epidemiologist checking a shared team e-mail account for new notifications of laboratory reports that were sent from clinical laboratories who had identified reportable pathogens in patient stool samples. These laboratory reports came as a PDF attachment of a standardized form including limited demographic information about the patient and their laboratory diagnosis (e.g. specimen collected, type, results). The epidemiologist created a new "incident ID number" for the patient in EDSS, and typed the patient's clinical and laboratory diagnostic data into the matching fields.

To make up for the fact that customization could not be built into EDSS and address additional foodborne-specific needs for extracting and analyzing data, the foodborne epidemiology team created a local database housed in a folder on a shared drive. The aim of the local database was to tie the clinical laboratory data together with the data that would be coming in later from the state public health laboratory. Though clinical laboratories sent laboratory report forms to the foodborne epidemiology team in the state department of public health once their diagnostic results were in, the clinical laboratories also shipped the isolate to the state public health laboratory to perform PFGE.

As I spoke with the epidemiologic team about extracting and analyzing data from EDSS, I learned that their local database helped serve as an accountability mechanism, to monitor the status of isolates and keep track of important information generated at different times by different players. Outbreaks are time-pressured health emergencies, where delays result in more people getting sick. Many delays reflect the friction between the second-order public health system and the first-order health care system. The local database, an epidemiologist pointed out, helped the team make sure that "we are getting all the information we need."[3]

The daily work of extracting and analyzing EDSS data began with the epidemiologist opening the local database, and creating new entries for the case data. A particularly important data field for this step was labeled "resolution status." Under resolution status, the epidemiologist chose to identify the cases as "suspect." The term suspect meant that the clinical laboratory had submitted a report with clinical diagnostic information to the department of public health, and likely (but not definitively) shipped the isolate to the state public health laboratory, but the state public health laboratory had not yet conducted its confirmatory testing on the isolate. When the state public health laboratory finished its testing, it would e-mail a laboratory report to the public health department with the test results. From this laboratory report, the epidemiologist would enter the testing results, as well as the isolate's laboratory ID number, marrying the epidemiologic case data with the laboratory isolate data. By marking the resolution status as suspect, it would be possible to monitor whether the other distributed entities in the chain of work had completed their tasks.

That EDSS had not been customized to support disease-specific needs was a significant source of friction for its users in their work to extract and analyze data, and many of the epidemiologists I spoke with would have liked to be part of the design decision-making. In a tight and precarious fiscal environment, building customization into design of the database was not prioritized. However, while EDSS certainly could have been designed differently to better support disease-specific needs, another aspect to this story is that multiple databases are often used to support different kinds of work, perspectives, and priorities (Bietz & Lee, 2009). The local database reflected the importance of getting information about isolates generated by others at different times, and linking the isolate data back to the clinical case data to enable outbreak surveillance.

Adapting to first-order change

While the local database attests to the crucial role that isolates play in foodborne outbreak surveillance, and helps play a role in creating accountability for isolates, it is not a tool that can compel data from heterogeneous infrastructures to come together. Reflecting on the power dynamics involved in second-order/first-order infrastructural relations, in a Working Group report, the Association of Public Health Laboratories (2014) emphasized that only some aspects of isolate "turnaround time" were within the control of public health laboratories:

> "When assessing laboratory testing turn-around-times for foodborne illness specimens, the steps from specimen collection to final results can be generally divided into those 'within our control' and those 'beyond our control'. The steps up through clinical laboratory analysis and submission to the PHL are often times beyond PHL control; however, there are ways in which public health can encourage and influence rapid and thorough submission of clinical isolates."

An outgrowth of America's patchworked federalist system is that states vary significantly in their legal mandates for disease reporting. While many states require reporting of case data, where clinicians and clinical laboratories are obligated to report diagnoses of notifiable diseases and limited patient data to local or state public health authorities, fewer states mandate clinical laboratories to conduct isolate reporting and ship isolates to public health laboratories.

In fact, the state I visited did not mandate isolate submission. Mandating the shipment of isolates would have made their consignment a part of clinical laboratory infrastructure. However, since clinical laboratories did not "own" this responsibility, second-order system builders at the federal level used the strategy of providing grant funding to incentivize clinical laboratories to submit isolates to the state public health laboratory. The grant money provided shipping containers to clinical laboratories, and paid for a specialized courier service to transport isolates from clinical laboratories to the state public health laboratory. What the grant money did not cover was the time and labor of the technicians in clinical laboratories to pack isolates in the subsidized shipping containers, and mail them to the public health laboratory. The constraints of this "soft money" program reflect the more general problem of fragmented and precarious funding for public health infrastructure (Baker et al., 2005).

When I toured the state public health laboratory, I saw evidence of major second-order friction threatening the interoperability of the health care and public health systems in outbreak surveillance. Near the laboratory entrance, several mundane items on a cart caught my eye. I was not surprised to see isolates fixed in agar slants and petri dishes, but I was surprised to see that the cart held orange-capped jars of stool specimens. I asked the laboratory technician why the stool specimens were there, because I had assumed that the clinical laboratories were always responsible for isolating bacteria from stool specimens. He clarified that this was not a frequent practice, but that the clinical laboratory who sent the samples had performed diagnostic testing on them using a "rapid" test, and had not isolated the pathogen from the stool. So the state public health laboratory asked the clinical laboratory to forward the stool samples on, so that it could isolate the bacteria for public health surveillance.[4]

The repurposing of isolates from the health care system has been a key element of the second-order system of foodborne outbreak surveillance, especially in the post-1990s era of molecular detection. However, the science and technology of microbial identification has not remained static, with increased development and uptake of culture-independent diagnostic testing (CIDT) in clinical laboratories. CIDT means that diagnostic results can be produced without needing to isolate organisms from samples, which would sever the key connection between the health care and public health systems that enables public health surveillance. CIDT methods offer several advantages over culture-based methods to clinical laboratories, such as more rapid test results, cheaper per specimen costs, shorter turnaround times, and lower complexity (Atkinson et al., 2013). Quicker and cheaper diagnoses can mean improved, more cost-efficient clinical care for patients.

However, some public health scientists have wondered whether these changes have heralded the opening of "Pandora's box," reducing the ability for both health care and public health surveillance systems to diagnose and identify diseases at the individual and population-levels (Janda & Abbott, 2014). As a second-order system, public health surveillance is particularly vulnerable to changes in the health care system. If CIDT methods are adopted before public health surveillance systems can adapt to the displacement of isolates, it will harm public health surveillance capacities like national foodborne outbreak detection, as well as the tracking of specific trends in infections (Cronquist et al., 2012). Cronquist et al. (2012) see the isolate dilemma as a difference in the values of the clinical and public health systems, in how the systems differently define what constitutes a "good" diagnostic test. There are shared values between sectors (accuracy, rapidity, cost), but also many differences in values and how those values are prioritized. Clinicians are oriented to treating individual patients, emphasize speed over accuracy, and typically need less detailed information about isolates. Public health practitioners are focused on the health of populations, may emphasize accuracy over speed, and typically need more detailed information about isolates.

One interviewee offered his reflections on this problem, identifying both economic and moral aspects to the friction around CIDT:

> Interviewee: The outside force, the commercial sector, wants to sell the latest and greatest test to laboratories that don't require a live organism… They are not interested in surveillance, they are interested in making money. It is a factor difficult to control.
>
> Interviewer: But is this [CIDT] meeting the needs of hospitals and consumers?
>
> Interviewee: It's hard to divorce what the hospital wants versus what the company wants. New generation products justify themselves by saving time. They are making inroads into laboratories, everybody wants the latest and best methods. Companies give laboratories machines for free, and then charge for the tests. They know laboratories can't afford the machines, but if the laboratories buy the assay for the next umpteen years… If the commercial sector was altruistic they wouldn't introduce these tests. There's no status quo, nothing's "good enough."[5]

Attesting to the second-order character of public health surveillance, the scientist framed the commercial sector as an "outside force" that the public health sector had difficulty controlling. He argued that the commercial sector was using a razor-and-blade type business model by giving away a platform and making money on buyers' subsequent dependency on the assays. The broader literature on the CIDT problem emphasizes the importance of stakeholder collaboration around finding solutions. But in the context of an interview, one scientist took a more pointed view, even raising questions about morality, "altruism," and when a test should be seen as "good enough."

As the operators of public health surveillance systems work to understand and ultimately solve the isolate dilemma, and try to maintain connections between the health care system and the public health system, they engage in creating expectations about the future. Expectations about the future are generative and dynamic, guiding present activities, defining roles, clarifying duties, fostering investments, and shaping strategies for leveraging opportunities and facing risks (Borup et al., 2006). In April 2012, several public health groups convened an expert consultation on CIDT, and "brainstormed potential solutions to address the anticipated impacts" of CIDT on public health surveillance (Association of Public Health Laboratories, 2012). During the consultation, one official stated that state public health laboratories were beginning to become the "primary entities" culturing specimens, rather than clinical laboratories.

The technician I spoke with in the state public health laboratory informed me that, on a small-scale, conducting isolation of bacteria from specimens in the public health laboratory was not an insurmountable problem. With their traditional microbiology training, staff in the public health laboratory had the technical know-how to perform isolations. However, to accomplish this shift at a large-scale, he surmised, more trained staff and funding would be required in public health laboratories. Increasing the amount of staff trained in traditional microbiology as well as building up laboratory infrastructure for traditional culturing did not necessarily make long-term sense, he pointed out. A major paradigm shift faced the public health system, which would involve the displacement of traditional microbiology and shift to computationally-intensive genomic and bioinformatic infrastructure.

The adoption of CIDT in the health care system is a change that threatens the connection between the health care and public health systems so crucial for outbreak surveillance. However, changes in other systems do not always result in risks to interoperability. Second-order systems can be adaptable, and changes in other infrastructures can result in improvements to second-order systems. This can be seen in the dynamics around a food system innovation. In the 1990s, supermarkets created computerized card-based programs to offer promotions to shoppers, as well as to collect and store individual purchase transaction data in computerized databases, a practice growing out of decades of marketing techniques employed to encourage shopper loyalty and increase consumer spending (Bellizzi & Bristol, 2004). As transaction data has accumulated, these databases have become "sophisticated competitive weapons" for electronic marketing, expanding beyond their initial function as a consumer discount delivery mechanism (Hammel, 1996).

Public health surveillance has been increasingly repurposing shopper card data to assist in outbreak investigations, and this method helps to address some of the limitations of traditional food history interviews. Understandably, consumers have difficulty recounting in detail every food item that they ate, especially if much time has elapsed, or if they are still feeling sick, or experience anxiety while being interviewed by a public health official (Mann, 1981). Seeing this phenomenon through the lens of repurposing adds further analytic insight. In everyday life, food is what people consume for the purposes of nourishment and enjoyment. The food history interview is a method for repurposing the food consumption practices of people as data for public health surveillance, and the (understandable) fallibility of human memory reflects the friction involved in this repurposing.

Several factors have enabled the second-order system to not just adapt to this change in the food system, but to help improve outbreak detection because of it. First, regulatory officials across federal and state levels are playing a more active role during outbreak investigations. Second, a data access process has been negotiated to manage friction associated with a complex set of laws. Laws governing the disclosure of shopper card data vary significantly across states, but in order to get shopper card data from commercial entities, public health officials usually must request shopper card numbers from individual cases and ask them to sign a consent form. Companies are not necessarily required to share information, but often times do so on a cooperative basis. Third, the second-order system has significant data analysis capability because of the central role that epidemiologic expertise plays in it. The frictions associated with incorporating shopper card data have more to do with the morality and materiality of repurposing than making sense of the data.

The second-order repurposing of supermarket card data for public health surveillance raises an interesting kind of moral friction illuminated by Nissenbaum's (2009) work on the politics of privacy surrounding different surveillance systems. Shopper cards are one of many examples of "dataveillance" in modern society, where people's day-to-day activities, interactions, and transactions can be tracked through information (Clarke, 1988). An important aspect to dataveillance is that information may be used for purposes unintended in the original design of tracking systems. In health care, Nissenbaum (2009: 6) notes, surveillance devices are lauded "hallmarks of high-quality care", while other surveillance activities, such as shopper loyalty card programs, are often criticized for infringing consumer privacy as retailers mine data for marketing insights. Public discourse on the repurposing of shopper card data for public health use reflects the moral friction surrounding dataveillance. In a media article (Vitals, 2013), one state public health official emphasized public health's careful safeguarding of information and limited use of data for illness prevention purposes, as well as performing professional boundary work (Abbott, 1988; Gieryn, 1983) between different government entities. The article quoted, "We are the government, but we aren't that part of the government… we're the good guys."

A great deal of material friction lies in the repurposing of materials and data from the food system, where public health workers must engage with the materiality of food records, and of food itself. Officials must process shopper card data in whatever form is given to them by companies, a form shaped by the companies' internal systems and the way that those systems export data. And though the repurposing of shopper card data has helped address some of the limitations of food history data, both only contribute to identifying possible food exposures. Only by tracing foods' journeys from the point of consumption back through distribution and production can investigators determine what food caused the problem and where it came from. My interviews with regulatory officials provided a picture of the frictions they encountered while repurposing food record data during traceback investigations. One state regulatory official shared how her department had to create an entire "war room" dedicated to a major traceback investigation.[6] Hand-drawn traceback diagrams on butcher paper covered the walls, and binders of paper records from suppliers FedExed to the agency filled the tables. The official used these examples to underscore how manual, time-consuming, and stressful the traceback process was for the staff charged with processing such heterogeneous data in the time-pressured context of an outbreak investigation.

Traceback involved a high amount of friction not only because each commercial entity created its own records for its own purposes in varying formats (paper and electronic), but that food itself did not remain a stable object in the process of traveling through the supply chain. Another regulatory official illustrated this issue by describing the traceback of a tomato moving through the supply chain. The whole tomato, she said, ripened from green to red in transit, and as it ripened, each color would transform how the tomato was categorized at different points in the chain of distribution, for example, entering in one place as a "vine-ripe," exiting as a "greenhouse," and recorded at retail as a "red round bulk."[7] Another official pointed out that not only did categories for tomatoes change, but the quantities and forms in which tomatoes were packaged also shifted throughout the supply chain.[8] He described how, once tomatoes go from fields to packinghouses, middlemen take them out of the boxes they were shipped in because tomatoes ripen at different rates. Tomatoes from multiple fields and farms are shipped to the same packinghouse. The packinghouse regrades and resorts the tomatoes, and may reuse the original shipping boxes, but place tomatoes that came from different fields and farms into those original boxes. Such practices of sorting tomatoes, he argued, were not reflected in the paper records. Significant second-order friction arose in managing the differences in the material production and distribution of food, record-keeping practices for tracking those processes, and repurposing those food records for public health use.

Conclusions

Second-order friction inevitably arises in systems that depend heavily on other infrastructures to achieve system goals. Adding the analytic vocabulary of repurposing and friction to the study of second-order systems helps to foreground the important role that the practical, skillful, and often times invisible work of actors within them plays in maintaining the connections between heterogeneous infrastructures. The concepts of repurposing and friction also help analysts connect this daily maintenance work to its larger sociopolitical and ethical consequences.

From a broader structural perspective, connecting the health care, public health, and food sectors is a difficult endeavor because each of these systems in their own rights is large, complex and distributed, with an array of different institutional actors. Two key objects that are repurposed from the health care system are the medical record and the isolate, so that relevant clinical and laboratory data can be woven together to inform outbreak detection. Second-order system actors encounter much friction in this repurposing work, whether they are winnowing clinical data, safeguarding protected health information through a layered relationship between the state and federal levels, or getting isolates to and through the public health system.

To manage that daily friction, multiple databases served as key tools. Faced with the constraints of a non-customized, cross-disease surveillance system built for the primary purpose of data input, actors in the state public health department created local databases as workarounds. In addition to databases, collegiality mattered immensely for smoothing second-order friction. As an object of joint responsibility, outbreaks served as a driver of relationship-building across distributed organizations.

Changes in other infrastructures typically pose threats to second-order systems. The displacement of culture-based methods in the health care system in favor of culture-independent rapid tests fits that general pattern. However, that public health surveillance could incorporate the change in the food system to create shopper card databases demonstrates that second-order systems can be adaptable. Additionally, building relationships between second-order systems and other infrastructures involves not just technical considerations, but political and moral ones. The problem of culture-independent testing demonstrates how much power the health care system has in defining what constitutes health, through its control over how materials from patients are transformed into data, for what purposes, and in which forms. The example of mobilizing shopper cards for public health surveillance highlights the moral frictions that can surround the repurposing of materials and data, as the traces of everyday life are turned into information that spurs action in the world.

The analysis of second-order friction in the repurposing of materials and data should be pursued in additional case studies. More work is needed to understand how second-order systems can adapt to changes in other infrastructures, as well as situations in which second-order systems hold power over other infrastructures. In particular, global health is a prime arena to investigate these dynamics. Some global health surveillance programs have disrupted fragile health care systems in resource-poor countries, marginalizing the building of local health care infrastructure in favor of attracting investment in top-down surveillance systems and categorical disease initiatives (Calain, 2007). The 2013–2014 Ebola epidemic in West Africa is urging some in the global health field to shift focus from addressing specific diseases to strengthening weak health care infrastructure (Barbiero, 2014).

Indeed, one of the biggest ongoing controversies in global public health surveillance involves friction over the repurposing of biological materials in disease reporting. In 2006, the Indonesian government stopped contributing H5N1 virus samples to the global influenza surveillance network run by the World Health Organization (WHO). Indonesia protested the WHO sharing virus samples with Western pharmaceutical companies, who used the samples to create new H5N1 vaccines, arguing that the prices for the vaccines charged by pharmaceutical companies were unaffordable. Though benefit-sharing policies have been put in place to make vaccine manufacture and distribution more equitable, innovations in the synthesis of viruses from genetic sequencing data may obviate the need to directly repurpose virus samples, a dynamic akin to the culture-independent problem discussed above. These benefit-sharing policies do not apply to genetic sequencing data since they do not define genetic sequencing data as "biological material" (Gostin et al., 2014). Conflicts can arise not just around how data are generated and moved, but because of differences in how "data" are defined and valued (Levin, 2014). Further analyses of second-order friction will help illuminate the serious moral and political implications of purposing and repurposing “materials,” “data,” and building interconnections between disparate systems and infrastructures.

Notes

1 Interview conducted 6/4/2013.

2 Interview conducted 6/3/2013.

3 Interview conducted 6/3/2013.

4 Field notes, 6/5/2013.

5 Interview conducted 8/16/12.

6 Interview conducted 11/19/13.

7 Interview conducted 8/2/2013.

8 Interview conducted 12/16/13.

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Good afternoon. I'm Gary Downey, senior manager at a large outpatient clinic and day care treatment center focused on hematology and oncology. Along with my colleagues, all highly-trained medical professionals and health care managers, I have to tell you that I'm truly going crazy.

Our health care workers are here to cure patients, but it's just not working. There's simply too much variation in our care.

It's so confusing. We have long been committed to proper standardization. You'll find here a foundational commitment to EBM, evidence-based medicine (pp. 61–68). Our practitioners rightly trust evidence from randomized controlled clinical trials. Indeed, we're participating in several trials right now, and we have to guarantee researchers that we're properly following their test protocols. Furthermore, drawing on EBM, we have developed solid sets of CPG's – clinical practice guidelines – to implement proven diagnostic and therapeutic knowledge (pp. 63–70). Finally, we have even developed and implement detailed ICP's – integrated care pathways – indicating precisely what actions our professionals are to take at each and every moment of treatment. We are even cutting edge in our understanding of the diversity of patients. We have distinct ICPs for different categories of patient based on sex, gender, race, ethnicity, and age.

But look at our schedule and the waiting room out there!! Waiting times for diagnostic procedures have gone through the roof. Patients don't comply with our schedules. And care—we're so crowded sometimes that some patients receiving chemotherapy have to sit on a stool rather than reclining properly in an adjustable chair. That is flat-out unsafe!

Again, I have to tell you: variations in delivery are preventing us from providing to our patients what we know is quality care.

Encountering the sociologist

A friend of mine over in the hemophilia care center in Chapter 1 tells me that this sociologist might be helpful. His name is Teun Zuiderent-Jerak. Since I'm not a Dutchman, I can't say (or sometimes spell) his name properly, so let me just call him Z-J.

My friend said that Z-J might be helpful, but not "useful" (p. 38). I didn't understand. She said he's not a sociologist who comes with solutions. He doesn't just identify factors that are supporting or hampering the implementation of existing policy agendas.

She said he'd hang out for a while, and I should be patient. She gushed about him suggesting an "experiment" that involved installing a multidisciplinary hemophilia clinic, including one site led by nurses and another for the physiotherapist (p. 55). "It worked!" she said.

So I gave him three months, here in Chapter 2.

Later – Situated standardization

After spending many hours watching, talking, and counting things, Z-J came back and somewhat brazenly told me that the bandwidth of our collective focus had narrowed. He said that we're focusing almost entirely on curative aspect of care rather than on other aspects that our professionals may not see as directly relevant to the continuation of treatment.

The main reason, he said, is that over the past three years, we've doubled the number patients that come through our doors. He says that he "learned" in the process of watching and counting that our definition of "good work" had shifted substantially. It's now about keeping up with the fast pace by whatever means necessary. (pp. 74–75). He showed me tables indicating that our hematologists are working far more surgery hours than we planned for them. Interestingly, though, our oncologists are not — but there's a huge variation among them.

Z-J then presented a proposal to undertake what he called "experimental" changes. These experiments were a bit weird. They threw out my understanding of organizational structure – outpatient clinic, laboratories, radiology department, clinical departments, and so on. They focused instead on processual pathways – flows of patients through the clinic.

We let him go ahead.

He kept redefining the place.

He showed us that doctors' assistants are not assisting if we define their work as either "front-office" or "back-office" (pp. 79–80). Instead of the easily understandable categories of sex, gender, race, ethnicity, and age, Z-J said we should focus on someone called the "emergency relapse patient." Another one is the "come-back-later patient," whose blood levels prohibit chemotherapy (p. 80). Z-J then aggregated practices based on these new categories of people, coming up with some new processual pathways.

In meetings with our staff, Z-J explained it all with simple one-page flow charts. Everyone found these far easier to understand than those 20-page integrated care pathways that, actually, we all hate. They really are hard to implement.

Just as my friend in the hemophilia center had predicted, Z-J told me he was not implementing a method. We pressed him a bit on this. All we could get out of him was "situated standardization" – standardization related to specific issues (p. 181). He explained how our incessant search for "standardized methods" are precisely what was generating the problems of variability and non-compliance in the first place.

We are now standardizing in a way that is situated in this clinic — it's not supposed to be universal. My friends at other clinics don't understand. I tell them that we've got a sociologist who "reconfigure[s our] problem spaces," whatever that means (p. 161). They're curious. They should be. Have a look at our waiting room.

Multiple ontologies

I've got an acquaintance in the Ministry of Health, over in Chapter 3, who's terribly worried about people seeing hospitals as unsafe place. I recommended ZJ and his colleagues (ok, not really).

They went over there with an assignment to "evaluate" an improvement collaborative designed to "improve safety" in health care. The Ministry's "Care for Better" initiative brought together multidisciplinary teams from many institutions. They were searching for best practices to spread across the country.

Evidently, Z-J was interested to see if his situated intervention stuff could work in a setting in which he couldn't just redefine the whole problem space, the way he did here. Project leaders wanted the team of sociologists to just "evaluate" the implementation of best practices.

But of course Z-J didn't behave.

Instead of proper evaluation, he and his colleagues started to document what they called "multiple ontologies" – a notion they borrowed from some other Dutch sociologist. I can't remember her name.

Rather than "acceptance of" or "resistance to" innovative practices, the sociologists saw distinct ways of "doing medication safety" that had specific consequences for the actions they afforded. One group did safety, they said, as controlling medication behavior by care workers and clients. Another did safety by reflecting on which errors were actually problematic, which were permissible, and when clients should delegate responsibilities back to care workers.

My acquaintance was evidently impressed, even if a bit uncertain. They persuaded him that improving safety might not be about visionary leadership successfully diffusing best practices across an organization, or a country. They said it could be about everyone recognizing that medication safety is done different ways. So, directly at odds with what all the evaluation experts tell us, repeatedly, they suggested that different teams might try formulating team-specific indicators for particular targets rather than assuming that everyone always does safety the same way.

Curious, I listened in on some conversations Z-J had with his buddies. Rather than importing a "theory of care," or a "normative approach" to medicine, Z-J says he's situating himself in the "surfeit of normativities" (pp. 189–190) that live on our wards.

He says he's conducting experiments by intervening. He says it doesn't matter if we develop some kind of shared commitments or not. He wants to help but says his value as a sociologist is not defined wholly, or even primarily, by whether or not his proposed solutions work. Since he claims not to be an organizational consultant, all the work is worth it to him if only if he is producing new knowledge about the conceptualization and delivery of medical care.

Z-J says that situated intervention doesn't work all the time or everywhere. It struggles especially when participants in a given problem space are absolutely resistant to rethinking their definitions, or recognizing other ontologies. I'm familiar with many such places.

He then went kind of theoretical on me, so I'm not sure if I got it right. Borrowing from Ian Hacking, Z-J has written a book that brings to sociology a back-to-Bacon movement that sees experiments as "fingerposts that are set up where roads part, to indicate the several directions" (p. 20). Z-J brings this notion to sociology because he wants to let go of what he describes as scholarly objectivism and scholarly engagement. Z-J questions both detached scholarly positions and pre-set normative agendas. His book makes the case that fingerpost experiments can produce new sociological knowledge.

Z-J argues that efforts at engagement tend to get stuck in a dualism. They risk either adopting the problem definitions pre-set by the actors they engage with, or becoming organizational consultants with their own problem definitions who are caught up in what Z-J calls the problem of implementation. That argument struck me as a bit familiar.

Z-J then went on to say that his experiments are about generating knowledge by reconfiguring problem spaces. They are about investigating what it means to situate one's work amidst previously unpacked normative complexities. They are about how unpacking normative complexities can be part of knowledge production and vice-versa, how intelligible theoretical positions must lie within the fields of practical action, and how intervention need not be tied to a predefined diagnosis of what the normative problem is, followed by implementation of a solution.

Along the way, Z-J evidently highlights the importance of material re-e figurations of medical practices, claiming that these reveal more, or at least different, knowledge than discursive ways of intervening. He labels this situated work "artful contamination" (pp. 185–186), pointing out that sociologists must accept the contamination of both their epistemologies and their normativities when doing experimental work. Finally, Z-J explains how "ecologies of intervention" (pp. 185–192) are both analyzable and matter greatly.

Some say it's a great book to think with. To me it sounds like a great book to "act with" (p. 9).

I think I'm going to buy a copy because I have a few questions.

1. I'm a little confused by this concept of fingerpost experiments in the back to Bacon movement. Do the fingerpost experiments that Z-J and his colleagues undertook in my outpatient clinic differ in any significant ways from fingerpost experiments in the natural sciences? Might the normative complexities differ in any way, e.g., in their levels of complexity?

2. What about those normative attachments to which Z-J devotes so much ink. Z-J acknowledges that fingerpost experiments have consequences for "scholars' resultant normative attachments" (p. 18).

Well, that made me think about the flow of chapters in this book. The chapters have a kind of narrative arc traveling through them. Z-J offers an account of developing, expanding access, as he moves from a hemophilia clinic to national evaluation standards. Somehow successes at various points led to opportunities at later point.

I did not notice in the book, however, an account of how all these fingerpost experiments has "resultant normative attachments" for Z-J and his colleagues. Does Z-J have such an account? Z-J is up-front about characterizing his interventions as helpful (e.g., pp. 34, 184) or as seeming worthwhile (p. 162). What happened to make these situated interventions helpful or worthwhile? And whom did Z-J become, or what commitments might he have added to himself, along the way?

3. Indeed, might this work raise important questions about the relationship between the person and the scholar in experimental work [and other scholarly work]? Might Z-J's account actually reframe the distinction between the person and the scholar by pointing out that the scholar [especially the scholar doing experimental work] is immersed in normativities as much as is the person? If the scholar is immersed in normativities to the same extent as the person, might it also be the case that the person is immersed in epistemics to the same extent as the scholar? Might accounts of scholarly learning, especially one focused so self-consciously on specific positioning of the scholar within the field of study, benefit from addressing more explicitly evolving relationships between the scholar and person? I myself have been playing with the image of multiple identities –added, subtracted, and with interacting agencies – to wrestle with this question. In Z-J's book, how is the scholar related to the person?

4. Ok, one last one. A small one. Z-J can surely answer it quickly: What's the difference between sociology and STS? Or put another way: How would the book's attachments differ if the subtitle read: *STS Experiments in Health Care*?

Zuiderent-Jerak Teun (2015) Situated Intervention: Sociological Experiments in Health Care. Cambridge & London: The MIT Press. 248 pages.

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In October 2015, we got together at Linköping University in Sweden to celebrate the publication of *Situated Intervention: Sociological Experiments in Health Care*. Each of us – with Jessica Mesman participating via tele-conference – presented a commentary on the book, and here we present a jointly written, cooked down version of the discussion.

Situated Intervention is based on an ethnographic account of Teun Zuiderent-Jerak's experience as a researcher advising on quality improvement and cost efficiency in Dutch hospitals at the beginning of the millennium, when the Dutch government was implementing a new insurance-based healthcare paradigm. Set within this wider context, the book narrates Zuiderent-Jerak's sociologically-informed attempt to intervene in the management and doing of health care *in situ*. It makes an original and audacious argument that such an interventionist approach does not just have practical advantages, but presents an especially effective, experimental method of *inquiry* into health care.

As such, the aim of the book is also to outline a methodological strategy, one that is closely engaged with practice but at the same time expands 'the narrow definition of usefulness in scholarly work' (p. 8). This expansion happens, Zuiderent-Jerak argues, through attempts at redefining various problems and problem spaces. The problems and problem spaces dealt with in the book are those of compliance, standardization, patient safety, and health care markets, and the book explores how these were dealt with in hemophilia, hematology and oncology departments. Expanding the problem definitions associated with these topics, however, is no smooth ride, as is demonstrated throughout the book.

The book then examines the bumps on the road of situated problem-solving, showing how the constraints we run into partly derive from the fact that the issues in question are already problematized by powerful societal actors and institutions, like doctors and hospital management, in partial, interested, and forceful ways. However, Zuiderent-Jerak does not shy away from attacking established truths in academic discourse as well as professional practice about the order of things in the hospital. For example about the nurses' role, about methods for visualizing care paths, or about the dynamics of health care markets.

Being present in the hospital, and becoming present to the distinctive and surprising problematizations emerging in this setting is what *Situated Intervention* is about. It is about the consequences of being equally responsible and accountable to health care managers, clinicians, politicians, patients, nurses, academic colleagues, and scholarly (inter)disciplines. It is motivated by the ambition to find ways of attaching differently to actors in a varied and dynamic field of action, where the good and bad, the relevant and irrelevant, have not been sorted prior to the study.

Situated standardization

Situated Intervention also takes on the challenge of attempting to bypass the binary beliefs that structure many of the debates related to the improvement of health care. Indeed, the book outlines the methodological strategy of situated intervention in relation to an impressive number of dichotomies: knowing and doing; the production of knowledge and the engagement with practice; objectivism and activism; a standardized and an individualized healthcare; experimenting and intervening; universal and individual; contributing to research and practice improvement; efficiency and quality, just to name a 'few'.

Zuiderent-Jerak argues that disputes along these oppositional axes prove to be unproductive to deal with the messiness and complexities of the lived experience in daily health care practices. When oppositions like the general and the particular act as the basis for improvement measures like standardization, problems will not resolve. Therefore, a different normative approach to problems of standardization should be explored: situated standardization. In this way Zuiderent-Jerak finds a way out of a dichotomized understanding of clinical practices without closing, 'bridging' or denying the gaps between the general and the specific, the real and the ideal. Situated standardization, he argues, is instead an attempt to re-orient our relation away from 'the big gaps', towards problems. This in turn enables a mode of intervening, in which we may attempt to re-negotiate relations, including those established by and with standards. Standards, in this view, are not the foundation to which clinical realities must adjust, but resources for action, i.e. temporary outcomes of a process-driven practice in which specific issues can be made available for (sociologically) unpacking. Now standardization is no more about implementation of pre-fixed norms, but about negotiable changes and a way of doing politics, in which the researcher is deeply involved.

With the notion of situated standardization the book moves away from health care improvement as the quest for 'finding answers to pre-defined problems' to 'the articulation of new agendas' (p. 158). In order to make this move Zuiderent-Jerak turns to Annemarie Mol's idea of multiple ontologies as analytical strategy to explore how different versions of 'the same' phenomena are enacted simultaneously. The simultaneity of different 'doings' of the world creates opportunities and limitations for action. By introducing the idea of multiple ontologies Zuiderent-Jerak provides us with a tool to explore the different ways in which compliance, standardization, safety or marketization arise as issues in practice. But in addition to unpacking the practices, Zuiderent-Jerak seeks to also re-pack them. Thus, the intervention is a two-step process: First, one empirically unpacks specific phenomena and issues. This can be done by experimental intervention: for example by adding a data logger to a blood cooling box and on the basis of the measurements discuss with the clinicians, who are eager to get different representations of patient worlds, what new knowledge is gained. Second, the elements that come out of this diagnostic process are conceptually, materially and organizationally re-assembled into a working configuration, based on what was already present in the situation. Thus, situated intervention is the result of a reconfiguration, not an intention set to bring in 'the new' or to 'fix' problems in the current health care system.

The problem of engagement

Situated Intervention is also about engagement. In fact, it is about engagements, as Zuiderent-Jerak presents two different forms of it and makes a passionate critique of existing approaches to both forms. The first form is about the engagement of social actors – patients, nurses, doctors – in healthcare practices. The second is about sociology's engagement in attempting to change the world. The book begins by reframing the problem of engagement that sociologists face. The problem of how to practice 'engaged sociology' is often misunderstood, Zuiderent-Jerak argues: it is assumed that the challenge is how to *apply* our knowledge, of how to do something ethical with the knowledge we have. Zuiderent-Jerak refuses this problem. Once we define our task as 'intervention,' it becomes clear that making knowledge and engaging normatively go hand in hand, he argues. This is also what the notion of the experiment teaches us: Especially when adopting an experimental approach *in fieldwork* settings, the experimental operates in an epistemic register as much as a normative one. In relation to intervention, consequently, the 'gap' between understanding and engaging disappears. It's an ingenious argument, among others, because it "empiricizes" the problem of engagement. When faced, for example, with widespread attempts in health care to couple the objectives of cost-saving and quality improvement, Zuiderent-Jerak asks: how do we intervene? This is an empirical question. It is a nice argument, but as Zuiderent-Jerak himself makes clear, there are issues…

For example, isn't there something distinctive about the capacities of social researchers, theorists and scholars for intervention? By giving up engagement, how can we continue to practice sociology, intervene sociologically? Zuiderent-Jerak included the term sociology in his title, something that is somewhat surprising for a book informed by actor-network theory (which after all is famous for its call to 'move beyond' sociology's notion of a society that can be intervened in. Yet, Zuiderent-Jerak nicely praises sociology as a distinctive form of 'making trouble', though he also notes that its condition of success is the reconfiguration of the problem space. (This gets potentially tricky, as there are now two objects of problematization in play: the researcher's engagement is 'problematic', but then there are also the problems of healthcare. But let's leave this aside for the moment.)

However, what is also striking about Zuiderent-Jerak's book is his seeming lack of concern about securing his identity as a sociologist. He is not afraid to adopt un-sociological vocabulary: Many of the book's most interesting problems are formulated in the vocabulary of health care management. For example, how to improve quality and save cost? In Zuiderent-Jerak's mode of intervention, these concerns become the sociologist's, and it thereby blurs the boundaries between health care management's concerns and sociological ones. Zuiderent-Jerak argues that sociological problems may become tractable in this way.

However, this raises the question: *what about tensions?* In doing both sociology and healthcare management at the same time, is Zuiderent-Jerak not presuming a win-win logic? A significant merit of the book is that it explicitly recognizes this challenge. It describes how in pursuing new ways of coupling quality and cost, this was *not* the outcome: Logic concerned with price ended up trumping quality. It was win-loose. In addressing this, Zuiderent-Jerak argues that we are dependent on wider ecologies of knowing and doing. He argues that we must recognize the need for 'artful contamination' between sociology and healthcare practices for intervention to stand a chance. But, how does intervention open up such a space for contamination, a space for encounter between different competences?

Here, too, Zuiderent-Jerak has an answer: situated intervention is intervention situated in *issues*. When problems emerge, an in-between space opens up, one where different actors (say nurses and doctors) are brought into relation. This we find terribly interesting. After all, situatedness used to be about situating stuff in specific situation at specific sites, but for Zuiderent-Jerak intervention is a way of getting involved in issues (i.e. the quality of care), and he proposes to include patient-centred care in issues. Even flowcharts, in his account, should be acknowledged as devices for articulating issues.

A further question emerges from this: How is intervention capable of opening a space of the in-between? Wasn't the argument that intervention does away with 'gaps? Here we should consider how, for Zuiderent-Jerak, intervention is also an alternative to participation. For him, participation is overrated, it is often sentimental (not based on inquiry), and risks to obscure power dynamics. He makes a relevant argument for intervention – as distinct from participation – on this point too. Intervention enables a focus on the patient-centred *organisation* of healthcare, something which Zuiderent-Jerak opposes to a more myopic focus on directly involving people, which he argues a participatory agenda often comes down to in practice. Zuiderent-Jerak's argues that patients are served better by a good flowchart than by doctors with limitless time to listen to them.

However, in advocating a shift from participation to intervention Zuiderent-Jerak runs the risk of closing down the space of the both-or and the in-between. Zuiderent-Jerak provokes us: Participation is sentimental, critique from an external position is 'easy.' But isn't participation something that brings about the in-between and connects relative strangers? Is not critique from a distance sometimes necessary for destabilizing normative complacency, and indeed for enabling precisely the unsettlement of established problem definitions, and the expansion of problem spaces, which Zuiderent-Jerak argues are so much needed? Why this need to reject participation and critique?

That said, so much is amazing about *Situated Intervention*. For example its definition of normativity: 'The capacity to respond to variability' (p. 190–92). There is an experimental ethos at heart of this definition, of trying things out, of finding out, of changing one's mind. But seeing variability among responses requires the multiplication of standpoints and identities. Zuiderent-Jerak's book takes us along on a passage through standpoints of patients, nurses, doctors, insurers, sociologists. Yet, he also shows how an interventionist sociology is able to multiply the identities of its allies, nurses for example. Health care organizations, from the perspective of the book, now become experimental, making experimenting interventions themselves all the time. This raises the question of how to mobilize this resource, this capacity to respond to variability? As Zuiderent-Jerak states on the book's last page social scientists can learn from this capacity and accept our normativity as embedded and enacted in practice. But how to take on the responsibility that experimentation in situ confers on experimenters? As Zuiderent-Jerak notes situated experiments inevitably operate in a normative register and expand the capacities for problem articulation and intervention not just in, but also beyond, situations.

Situated Intervention: Response to Comments

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"So why are *you* wearing a tie today?"

"Well, I'll have to leave a little earlier. I'm acting as opponent again this afternoon in Leiden. And yourself? Off to another guideline meeting in Nice?"

Five people are taking their seats at a small meeting table in the office of an oncology professor at a large Dutch university hospital. Two of them are professors of oncology and haematology. The other three are made to listen to this exchange of importances. Two of them are specialised oncology nurses. The last one is me. None of us are wearing ties.

This group is meeting to discuss the delegation of some of the oncologists' tasks to these specialised nurses. It seems like *everyone* in the room is sceptical. The doctors are sceptical about the skills the nurses bring to such nurse-led clinics. "Before we start, we should perhaps still train some conversation-techniques with you?", the oncologist suggests.

"Talking about conversation skills!", one of the nurses snaps, as soon as the doctors have left us to go to their important elsewheres. "That bragging about their ties shows how great *they* are at that! 'Conversation-skills'… That is what our whole education was about!" They are a little more than sceptical about the understanding the doctors have of their work, and of how they will be able to cooperate in such clinics.

And me? Well, I'm sceptical about the chances of success of delegating tasks within a setting with such fraught politics of professions. But I've been reading Suchman, Star, and so many other of my heroes of feminist STS scholarship dealing with the politics of workplaces (Suchman, 1995, 2000; Star, 1991; Star & Bowker, 1995; Star & Strauss, 1999). And conceptualising what I'm encountering here as 'making skilful invisible work visible' is surely more interesting than sociology of professions' analyses that reify rather than reconfigure power relations. So, I guess we'll just keep going with the experiment of setting up nurse-led clinics, and meanwhile enhance the legitimacy of the nurses by organising professionalization sessions on the ward for nurses, to show to the doctors that they do really have the skills to take over some of their tasks.

During the first of those training sessions on cutting edge developments in chemotherapy, something puzzling happens. The nurses start asking so many questions about the regular chemotherapies they administer on a daily basis, that the instructor has to change his training to focus only on basics aspects of their everyday work. "You know," the nursing manager afterwards tries to justify, "this is just part of how things are around here. We are an outpatient clinic and day care treatment centre, and most of the nurses don't work here because of their interest in oncology, but because they never have to work nights or weekends. They just want to be on time to pick up the kids from school."

So what was I to make of this?! I *love* that scholarship on skilful but marginalised invisible work! The work that shows that the skilful work of for example nurses often is invisible, though not in the sense that it cannot be observed, but, as Star and Strauss (1999: 20) wrote, "if one looked, one could literally see the work being done—but the taken-for-granted status means that it is functionally invisible." How to deal with the fact that, now that I was trying to undo the taken-for-granted status of nursing work, this brought to the fore the *unskilful* invisible work that was going on at the ward? What could this surprise mean for what I was to do next in this improvement project, for scholarly understandings of invisible work, and for my normative attachments to making visible marginalised work practices?

Struggling with such questions is what made me write *Situated Intervention*. How can the direct involvement of STS scholars in the practices they study lead to the production of interesting STS knowledge and normativity? What is there to gain from intervening in practices to learn from such experiments that tell us something about the field and about ourselves, both in terms of our scholarly as well as our personal attachments?

The generous and inventive readings of the book presented here raise some serious questions. Here I take those questions as invitations for further situating the book as itself an entity to think with and through within ongoing concerns within STS. As far as I can see, the puzzles raised relate to five topic areas: to what extent are the situated intervention experiments encountered here highly specific, what are the losses of contrasting situated intervention with other dearly held notions such as participation, how to solidify an emergent approach to intervention, how does situated intervention relate to the becoming of the person/scholar, and what about the relationships between sociology and STS. These are five areas that each in and of themselves would require extensive comments, so my thoughts on them here are merely the start of what I hope are longer conversations.

The specific of these situated intervention experiments

Both commentaries raise questions about what is specific about the experiments explored in the book. The senior manager, Downey, wonders how such fingerpost experiments in his clinic relate to scientific experiments in the natural sciences, especially in relation to their normative complexity. I would agree that one of the reasons why I have a particular interest in studying health care practices, is that their normative complexity is nearly impossible to avoid. So there are indeed reasons for exploring situated intervention experiments in this particular empirical domain, which of course is not to say that scientific experiments are devoid of such normative complexities. The work of scholars like Sarah Kember (2003) is one of the inspirations for the book, and her work is focussed on finding frictions within practices of scientific experimentation. So although health care surely is not indispensable for the argument of the book, exploring the production of new knowledge and new normativities through experiments in health care could be seen in line with the advice given by Howard Becker (1967: 246), and that I draw upon in the book, to study "impartially," meaning that scholarship should be applied so that "a belief to which we are especially sympathetic could be proved untrue." If putting our beliefs at risk is central to situated intervention, situations like the one I introduced above are not the *problems* but the *product* of situated intervention. Normative complexities are not merely *encountered*; they are *produced*. This makes me hopeful for the ability of situated intervention experiments to produce normative complexities in a wide range of empirical domains.

Opening up problem spaces: What about participation

Given that the book is about situating interventions in sociologically unpacked and produced normative complexities, what are our repertoires for doing so? And more specifically, ask Marres, Mesman and Wintherelk, what about the important repertoire of participation? Isn't participation one of our main resources for opening up a space 'in between' whatever binary opposition we encounter, because of its ability to connect relative strangers? My reply to that would, in common parlance, have to be: let's see. More in line with the argument of the book I would say: let's try. Although participation may well be crucial for articulating frictions within certain practices, this is not necessarily so. I was alerted to this by the predominance of calls for 'patient participation' as part of health care quality improvement and for the development of patient-centered care. And although I am obviously sympathetic to the idea of participation, I was taught quite a lesson about my sympathies by a mentally disabled resident of a care facility that was part of a national improvement program for long-term care. In the book I describe how she gave a presentation on the client board that she chairs and that is set up as a Trust, separate but in a loose liaison with the care institution in which she lives. Supported by an attendant employed by the Trust, she explained how the previous client board of the care institution had been absolutely unworkable for clients. When they were invited to attend a meeting, in preparation they had to work their way through piles of documents that had not been written for them and were hard to understand. In their own Trust, the clients set their own agenda for which they may or may not take suggestions by the board into account. The Trust organizes thematic meetings with no more than one topic on the agenda. The members prepare for the meeting by making a short movie about the issue they want to discuss. After the discussion, they come with recommendations to the board. In her presentation, the client problematised the notion of participation: "We are unique: in other places you are allowed to 'participate.'" On the last word, she pulled a disgusted face, drawing quite some laughter from the audience. The laughter came from the stunning clarity by which a mentally disabled client could problematize a notion that was held so dearly in the improvement program. So although participation may in some instances be a crucial aspect of situated intervention, I like to follow a second bit of advice I take from Becker. Especially towards dearly held notions like participation, scholars may want to "avoid sentimentality," meaning that we should not shun finding out "what is going on, if to know would be to violate some sympathy" (Becker, 1967: 246). This also means that the question whether participation is a helpful notion is highly dependent upon the issue at stake. So in attempting to empiricise concepts like participation, the issues get more of the credit they deserve, as Marres (2007, 2012) has pointed out so well.

Solidifying emergence

If theoretical STS notions, scholarly normativity, and interventions all are in flux, and crucially so, how then to solidify this process of situatedness and flexibility? If situated intervention is about creating something new that was already there but that could only be brought into being by challenging common understandings of, say, health care markets, standardised care pathways or patient safety, how then to consolidate the adaptive strength? It is unsurprising that Marres, Mesman and Winthereik raise this question, especially given Mesman's (2015) interest in 'exnovation', that is making visible and highlighting competencies and resources that have been "overlooked or forgotten". They thereby focus on precisely one of the toughest challenges of situated intervention. In a sense, I think of this question as the puzzle of intervening less. Although I am largely suspicious of more-less renderings of scholarly debates, to counter a concern I have about this book being read as a call for 'more intervention', I would like to stress that at times the most important interventions where those that were less specific than expected by actors in the field. In a national improvement project focussing on the redesign of the care trajectories for oncology and elective surgery patients, I asked teams to draw intentionally sketchy flow charts. This was particularly challenging since flow charts are often part of the development and introduction of integrated care pathways, and the quality managers working in the program had learned to map and describe each step in the care process, redesign it, and implement the redesigned process—exactly the kind of separation of innovation and implementation that I fervently tried to avoid. Such a pragmatic and sociologically inspired way of doing standardization, that drew upon a processual understanding of pathway*ing,* therefore caused quite some frustration among quality managers trained in a more rigid approach. It actually led to complaints about the program being insufficiently helpful in providing access to best practices, which we countered by providing a map of which hospitals were working on which topics, including the phone numbers of the contact persons there. With this we tried to speak to their concerns about learning more from each other, without specifying which practices were 'best'. This may now however sound easier than it was. It was actually very hard to keep standards sketchy, and to highlight the process of standardisation rather than the production and implementation of standards. And where this was hard in relation to standards within health care practices, it was equally hard for normative concerns in scholarly debates. There also, there were repeated calls for specifying 'Archimedean ethical points' which, I was told, would be needed to avoid doing 'just management' and reducing scholarship to 'normative empiricism'. Trying, with Canguilhem, to define the capacity for normativity as the variability in response (Canguilhem, 1994; Brown & Stenner, 2009: 160) was therefore equally challenging as keeping open and resisting the fear of inaction (Jerak-Zuiderent, 2015) in the face of calls for products of health care improvement. In this sense, the hardest part about exnovation seems to be not just the shift of the STS scholar to focussing on letting something new emerge that is already there, but to keep doing so in the light of repeated calls for external answers – both in terms of health care improvement and scholarly normativity.

Emerging scholars

To what extent are STS scholars the product of situated intervention? If scholarly attachments are put at risk, what does this do to the researcher beholding such attachments, especially when the practices encountered need to be taken almost more seriously than the scholarly concerns? These are important questions that Downey raises. I would say that needing to take the realities encountered and understood by the field seriously has, in scholarly terms, often been more of a gain than a loss. In the case of delegating tasks to oncology nurses, I surely tried to fight the understanding of the site that the doctors displayed by not trusting the skills of the nurses. And if I had done a more traditional ethnographic study of health care work, I could have quite easily turned my empirics into a story about invisible work resulting in problematic workplace design. But when trying to develop the nurse-led clinic, it simply proved too hard to maintain my critique of the doctors' understanding. And these are the kinds of situations that made me realize that, paraphrasing Suchman and Trigg's (1991) concept of 'artful integration', situated intervention should be carried out with the aim of achieving 'artful contamination'. Where contamination stops STS from getting locked into pre-given problem spaces, "anti-bodies" have to be artfully cultivated by being part of STS conversations. And indeed, this means that distinctions between the field, the scholar, and the person become profoundly problematised. As a result, I have come to appreciate the value of standardization that is situated in specified understandings of a setting and thereby have come to love standards in a way I hadn't imagined, while becoming increasingly sceptical about any normative standards in the form of scholarly attachments that pretend not to need such situatedness because of their obvious superiority. This doesn't mean that I am no longer attached to notions like 'invisible work', but that I have become pertinently aware of the risk of failing to specify why, here, for whom, and at what costs - even in the case of seemingly superior notions.

Sociology and STS

The last question raised by Downey raises a huge topic, while I will only be able to provide a very short response here. What about the difference between sociology and STS? What would happen if the subtitle referred to STS experiments? In honesty, the request to open up the focus of the debate from STS to a wider audience came from the publisher and the reviewers. At first I was sceptical about this. Having a disciplinary training in the interdiscipline of STS, I saw little value in and felt fairly insecure about engaging with wider sociological debates. But I must say that the journey into sociological debates offered quite some pleasant surprises. It was for example fascinating to find that debates about taking sides in urban sociology contained nuanced positions that had a lot to offer to debates on captivity in STS. Being of a generation that, ironically speaking, at times seems to consider STS to be a field that was 'discovered' in Paris in 1987, I started out adhering to reviewers' demands and ended up learning much about the inspiration the pre-histories of STS can offer. For example, Becker's advice to acknowledge attachments while avoiding sentimentality about them turned out to be a crucial element of situated intervention. When I did not find the expected 'skilful invisible work' among oncology nurses, as I described at the start of this response, I did not simply give up on dearly held attachments to this notion. We rather started out with a dedicated nurse-led clinic that aimed more modestly at the improvement of general communication with patients about their treatment. This allowed at least for a much-needed collaborative connection between oncologists and nurses, as now they would have to begin working together and discussing their findings during consults. And it equally allowed me to be attached to a notion like invisible work, but in a somewhat more detached way. My hope is that exploring the relevance of earlier sociological debates for current scholarship modestly contributes to resisting the hardening of disciplinary boundaries rather than to territorial claims about STS mainly being part of one or the other of it's related disciplines.

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A strange sense of excitement and unease came over me as I started to read this book. I had not anticipated so many references to STS would appear in an anthropological text. Then when arriving at the chapter 'Worlding the Matsutake Diaspora' by Anna Tsing (2010), I suddenly encountered a reading of the STS canon which I had not considered before. I felt my own assumptions about my discipline being questioned, and that something had come up that STS scholars and anthropologists must discuss; that here were new connections and separations to be made across and between our disciplines. I come back to this feeling in concluding my review, but first I explain my initial put-outness.

Tsing's chapter is one of 12 contributions by leading anthropology scholars collected and curated in this volume. In different ways each of these chapters explores the notion of 'holism' in current anthropological theory and practice, and takes on the task of considering whether this concept – as a frequently critiqued aspect of traditional anthropological work – might continue to play a significant role within the discipline. These authors draw from their own research to examine these concepts in different ways, suggested by the editors as examinations of 'holism in ethnographic practice', and as ways of moving beyond cultural, structural and social wholes as an assumed basis of anthropological work.

In her chapter, Tsing argues that contexting, or 'worlding', is a practice carried out by the ethnographic researcher as they ascribe, often quite incorrect, explanatory frames to research material and experiences. Nonetheless, it is the work of describing this frame, which allows the researcher to develop knowledge claims about empirical research data, through enabling the inclusion of phenomena that at first was not visible or appeared insignificant. To make this point, she differentiates between the significance of 'context' for anthropologists, and STS scholars. She suggests that while anthropologists are always seeking to put things in context, research in science studies denies the existence of context altogether, preferring to work with and through unmediated actor-networks in the making.

This assertion came as a shock. I wanted to exclaim that it was *not* that this early work in STS denied the existence of context. The point STS attempts to make is that what 'contexts' might be assumed to 'be' is radically contingent.

The way that Tsing makes her claim about the distinction between STS and anthropology is by referring to Michel Callon's (1986) paper on the Scallops of St Brieuc Bay. She recognises that this paper is considered a classic because it shows how actor-networks involving both humans and non-humans make things happen; but at the same time, she also notes that there are questions that the paper does not ask. For example, why is it that only French scallops and scientists make it onto the list of relevant actors in the network, when at the start of the story the Japanese were also involved? (Tsing, 2010: 48)

Tsing's point in noticing the omission of Japanese scallops and scientists within Callon's story, is that empirical research texts only narrate events as they appear as significant within someone's judgement of what counts as an appropriate whole. In the case, she suggests, that Callon's version of 'worlding' fails because this decision to include the French – but not the Japanese – was never noted or explained within the text.

This was interesting, because for me this paper has always been masterly in the way it takes on the assumption embedded in (probably still) prevailing philosophies of science that scientific inquiry involves the discovery of facts about a passive external world out there waiting to be known. By bringing non-humans into the picture as active participants of scientific knowledge production, previously unassailable claims of scientific objectivity began to crumble. As such, this paper offered an intervention into an epistemo-political context, one in which such an intervention was desperately needed.

Now, should I ever have occasion to negotiate with an anthropologist about this in some future interdisciplinary project, my assertion might be, that in writing this paper Callon was certainly 'worlding', but not in the sense that anthropology 'worlds'. It was not Callon's intention to produce a comprehensive account of a specific geographically bounded instance of knowledge making. Such a task would have necessarily left unexamined the associative and descriptive task of producing sociality, locality and scale within knowledge work. And would have short-circuited attempts to show science might recognise contingency within its own practices, and therefore disrupt prevailing objectivist narratives.

My aim in having such a conversation with some imagined future anthropological colleague is to begin to notice a radical difference between contexts: assumed global geographies of inclusion and exclusion here, and political orders emergent in epistemic practices there. *Such a provocation to thought, contains within it the capacity to engender recognition of difference*. That is what seems to be key to recommending this book outside of anthropology.

At the start of the book the editors talk about the motivations for this inquiry into holism, a key tenet of anthropological research throughout the 20th Century. They tell how a number of Scandinavian anthropology departments initiated a series of events aimed at exploring anthropology's past failings and its current practice. The aim was to become better able to support new anthropology graduate students who, it is assumed, will inevitably find themselves working with ethnographic methods that are continually changing, and in building careers through interdisciplinary collaborations.

As an STS scholar I was dazzled and enthralled by the vibrant descriptions of people, places and cosmologies. I was also impressed by the capacity for various groups of scholars in the discipline of anthropology to generate such a detailed and thorough exploration of a concept and methodological practice, at a time when far more tangible research outputs are often required, and the academy in general seems to have abandoned its support of disciplines as a core part of its being.

However, I was also surprised that amidst the very many versions of holism – past and present – that appear in this text, there were none that stepped beyond a consideration of holism as an *epistemological* matter; that is, as a means for producing better or worse empirical accounts of diverse external realities. Remembering my own beginning days as a PhD student, it was being sensitised to the ways in which wholes and parts are proposed as an *ontological* multiplicity in STS that helped me to recognise multiple natures appearing in the patches of bush where I was doing my fieldwork. Helen Verran's (2001) work with number, and Annemarie Mol's (2002) work with bodies, both find ways to show and work with ontological multiplicity by projecting new virtual wholes within which questions of what is known, by whom and in what way, are able to figure within analysis. It was under the guidance of such approaches, that within my own research work I was able to begin the process of charting a new nature coming to life under the influence of neoliberalism.

Paradoxically the book succeeds in being of interest beyond anthropology precisely because it is *solely* interested in anthropology. In looking for ways to support new anthropologists to move into interdisciplinary collaborations, the rich detail provided in the very different chapters of this collection help to highlight both the potential and the limits of disciplinary practice, and in so doing provides much fodder for discussion between anthropologists, and their collaborators. It is an exemplification of such a challenging engagement that I have presented here in this review, and no doubt many more lengthy and more elaborated debates will emerge out of reading of this text, both by scholars of anthropology and other disciplines.

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