
Actor Network Theory and Sensing Governance: From Causation to Correlation

David Chandler

University of Westminster, UK

This article is organized in four sections. The first section introduces sensing governance in terms of the governance of effects rather than causation, focusing on the work of Bruno Latour in establishing the problematic of contingent interaction, rather than causal depth, as key to emergent effects, which can be unexpected and catastrophic. The second section considers in more depth how sensing governance enables politics by other means through putting greater emphasis on relations of interaction, rather than on ontologies of being, and links the methodological approach of sensing governance closely to actor network assumptions that disavow structures of causation. The final two sections analyze how correlation works to reveal new agencies and processes of emergence and how new technologies have been deployed in this area, providing some examples of how the shift from causal relations to sensing effects has begun to alter governmental approaches.

1. Introduction

Sensing governance develops the possibilities of doing politics by other means through the application of new technologies for data analysis. It is argued here that the emphasis on these new technologies displaces modernist forms of politics with worrying consequences. New technologies, enabling new possibilities for governing, have been developed across contemporary society, from the technologies of the quantified self to the application of data analysis in schools and businesses, to the development of new sensing capacities through international collaborative initiatives. It is this broader shift in both practices and understandings that support the argument made here that new technologies of sensing are increasingly enabling politics by other means. This displacement can be seen clearly at the highest levels of policy-making, including the United Nations' Global

Pulse, established by the UN Secretary-General to research and coordinate the use of Big Data for development,¹ the World Bank's Open Data for Resilience initiative (OpenDRI²), seeking to see the emergence of natural hazards and the impacts of climate change in real time, and the PopTech and Rockefeller Foundation initiatives on Big Data and community resilience.³ Sensing governance relies heavily on the construction of non-modern ontologies in which the world appears through processes of emergence. These framings highlight the development of new post-epistemological approaches, which view correlation as a more reliable and more objective "empirical" method than the extrapolations and predictions of causal analysis.

This article argues that sensing governance works on the surface, on the "actualist" notion that "only the actual is real" (Harman 2010, p. 180; see also Harman 2009, p. 127). As Roy Bhaskar, the originator of the philosophy of critical realism, has argued, "actualism" can be seen to be problematic in that hierarchies of structures and assemblages disappear and the scientific search for "essences" under the appearance of things loses its value (Bhaskar 1998, pp. 7–8). It is for pragmatic reasons that politics through other means, through sensing, appears to be emerging. Sensing governance accepts that little can be done to prevent problems (understood as emergent or interactive effects) or to learn from problems and that aspirations of transformation are much more likely to exacerbate these problems rather than solve them. Rather than attempt to "solve" a problem or adapt societies, entities or ecosystems, in the hope that they will be better able to cope with problems and shocks, sensing governance seeks to work on how relational understandings can help in the present; in sensing and responding to the process of emergence.

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1. United Nations Global Pulse initiative website: <https://www.unglobalpulse.org/>.
2. The World Bank's Open DRI webpages: <https://www.gfdr.org/pendri>.
3. <https://www.datapopalliance.org/>; and for the Rockefeller Foundation: <https://www.rockefellerfoundation.org/our-work/current-work/resilience>.

of how the shift from causal relations to sensing effects has begun to enable politics by other means.

2. Sensing: The Governance of Effects

Sensing governance understands problems in terms of their effects rather than their causation. Understandings of causality have long been at the centre of philosophical debate and at the heart of disagreements over statistical probability; today, these discussions are no longer limited to philosophers and mathematicians. In contemporary policymaking, analysts are much more likely to highlight that the complexity of global interactions and processes mitigate against ambitious schemas for intervention, aimed at finding the root causes of problems or developing solutions through ambitious projects of social and political engineering from the ground up (see, for example, Ramalingam et al. 2008; Ramalingam 2013). In a more complex world, linear or causal ontologies can appear to be reductionist and are easily discredited by the growing awareness that any forms of governance intervention will have unintended side effects. The concept of “unintended consequences” was initially developed by the American sociologist Robert K. Merton (1936), in his influential article “The Unanticipated Consequences of Purposive Social Action.” While Merton focused on mitigation through emphasizing the ideational or psychological reasons for ignoring or being blind to unwilled consequences, in contemporary discussion these are now cast as unavoidable or as ontological problems. It is in the attempt to minimize these unintended consequences that the focus of policy-makers has shifted to “sensing governance,” focusing on the responsive governance of effects rather than seeking to address ostensible root causes. For example, rather than seeking to solve conflict or to end it (resulting in possibly problematic unintended consequences) international policy intervention is increasingly articulated as managing conflict, developing societal strategies to cope better and thereby limit its effects (Department for International Development et al. 2011). Focusing on managing effects rather than engaging with causative chains makes the forms and practices of policy intervention quite different.

The link between conceptual discussions of governance and epistemic questions of knowledge is usefully highlighted by developing Giorgio Agamben’s framing of a shift from a concern with causation to that of effects, which he understands as a depoliticizing move (Agamben 2014). Debates about addressing causation involve socio-political analysis and policy choices, putting decision-making and the question of sovereign power and political accountability at the forefront. Causal relations assume power operates in a hierarchy, with policy outcomes understood to be products of conscious choices, powers and capacities. Agamben argues

that, whilst the governing of causes is the essence of politics, the governance of effects reverses the political process:

We should not neglect the philosophical implications of this reversal. It means an epoch-making transformation in the very idea of government, which overturns the traditional hierarchical relation between causes and effects. Since governing the causes is difficult and expensive, it is more safe and useful to try to govern the effects. (Agamben 2014)

The governance of effects can therefore be seen as a retreat from modernist or causal assumptions of governance and to enable politics by other means. However, the shift from causation to effects involves a shifting conceptualization of governance itself. Sensing governance—governing through attempting to enhance system and community responsiveness to effects—shifts the focus away from the formal public, legal, and political sphere to the capacities and abilities of systems or societies for responsiveness to changes in their environmental context. The management of effects involves redistributing agency understood as responsive capacity, and thereby evades the question of formal governmental responsibility or accountability for problems or the need to intervene on the basis of government as a form of political decision-making (see further, Chandler 2014b, 2014c).

Policy interventions have shifted to sensing governance as governing agencies have sought to respond to the effects of indeterminacy and risk as inherent in the complex and interdependent world rather than understanding problems in a modernist telos of solutionism and progress. Problems in their emergence are the ontological product of complex feedback loops and systemic interactions that often cannot be predicted or foreseen in advance. Surprising and catastrophic effects thereby call for new ways of thinking and governing: ways that go beyond modernist linear cause and effect assumptions and that can potentially cope with unexpected shocks and unseen threats.

As effects become more central than causes, “solutions-thinking” becomes less useful and potentially a barrier to responsiveness, this is because problem solving tends to affirm current practices and approaches rather than emphasizing the need to be alert to emergent effects.⁴ The promise of solutions seems to deny our entangled responsibilities and commitments while greater sensitivity to effects enables us to become increasingly aware of them. Initially, the leading theorist to problematize

4. Robert Cox prepared the ground, famously differentiating approaches that saw problems from a narrow status-quo perspective from those that sought to critically rethink the bigger picture (1981).

problem solving approaches was perhaps Ulrich Beck, who argued that the risk of unintended effects could no longer be bracketed off, compartmentalized, or excluded in the Second Modernity (Beck 1992). Beck argued that unexpected feedback effects from policy making were an inevitable result of globalization and interconnectivity; suggesting that the boundaries of liberal modernity, between the state and society and between culture and nature, were increasingly blurring. Surprises and shock events could no longer be treated as exceptions to the norm, to be quantified and insured against.⁵

The radical awareness of interconnectivity and feedback effects, articulated by Beck, was initially presented as purely negative: as a factor to be addressed, and potentially minimized, through governing under the “precautionary principle.”⁶ The awareness of entanglements leading to unintentional effects thus began to integrate concerns of contingency into the practices of governance. The precautionary principle of Beck’s still had a modernist legacy, in the positing of a potentially knowing and controlling subject able to manage unintended effects. But, as the assumptions of modernity began to ebb away and discourses of globalization morphed into those of the Anthropocene, this subject increasingly had to act more humbly and cautiously, testing, and experimenting rather than assuming cause and effect modalities.⁷ Unfortunately, Beck focused on the regulation of effects through ways of predicting or imagining the consequences of human actions, which seemed logically impossible to foresee. For example, even if scientists reached a consensus on the safety of a new procedure or initiative before its application, scientific experimentation in the laboratory cannot reproduce the same conditions as those of real, differentiated, and complex life. This then led critics, like Bruno Latour, to convincingly argue that, once included, effects could not be prevented or minimized through precautions but instead had to be followed through “all the way” (Latour 2011, p. 27).

Bruno Latour sought to go beyond the limits of Beck’s work in this area, advocating that we trace the effects of human actions in real time feedback loops: requiring less of the imagination and more of digital

5. On the importance of the normalizing effects of insurance see, for example, Ewald 1991; Defert 1991; Dillon 2008.

6. He argued: “If we anticipate catastrophes whose destructive potential threatens everybody, then the risk calculation based on experience and rationality breaks down. Now all possible, to a greater or lesser degree improbable, scenarios must be taken into consideration; to knowledge drawn from experience and science we must add imagination, suspicion, fiction, and fear.” (Beck 2009, p. 53)

7. For the critics of the principle, which has been taken up in a number of ways in international policy documents, the problem was the paralyzing aspects of “possibilistic” thinking (see, for example, Sunstein 2002).

science and technology. Latour has deployed the radical discourse of understanding problems in their emergence to great effect, having long waged war on modernist binary understandings, particularly that of the separation of culture and nature. For Latour, just as humanity has become more entangled with nature than ever before, ecologists have sought to emphasize the need for separation to protect nature and, modernist science aspires to know the world/nature as somehow a separate and fixed reality (see, for example, Latour 1993a, 2004). Therefore, along similar lines to Beck's later work, global warming is not so much a sign of the failure of modernity but an enabler of new forms of sensing governance in the Anthropocene. The awareness of emergent effects such as climate change reveals the entanglements of humanity and the environment and is a critical wake up call to radically reorganize the governance of the planet on the basis of a more inclusive understanding that "nature" cannot just be left alone, but must be "even more managed, taken up, cared for, stewarded, in brief, integrated and internalized into the very fabric of policy" (Latour 2011, p. 25).

Sensing governance is crucial for Latour's project of enfolding the unintended effects of planetary interaction into the everyday governance of the Anthropocene. The effects of interaction are understood to be concrete and contingent and thus depend on the ability to trace these, following the unintended and unforeseen consequences of human actions "all the way." Latour enthuses:

... the principle of precaution, properly understood, is exactly the change of *zeitgeist* needed: not a principle of abstention—as many have come to see it—but a change in the way *any action* is considered, a deep tidal change in the linkage modernism established between science and politics. From now on, thanks to this principle, unexpected consequences are attached to their initiators and have to be followed through all the way. (Latour 2011, p. 27)

For Latour, every individual is the initiator of actions and thereby responsible for the interactive consequences of this initiation.⁸ He argues that the consequences of these human actions should be traced through seeing or being sensitive to the network formed through their effects.⁹

8. Exemplified in the example of Frankenstein's failure to care for his creation, which then turned into a tragic monster, Latour 2011.

9. See, for example, Clark 2010; or Klein 2014, pp. 1–3, which opens with the ironies of anthropogenic feedback loops; for example, when extreme hot weather, caused by the profligate burning of fossil fuels, melted the tarmac and grounded aircraft at Washington DC in the summer of 2012.

Thus sensing governance seeks to trace these links on the surface. The need to be responsive to effects also drives debates establishing the networks of entanglement of the Anthropocene, calling for greater sensitivity to the everyday feedbacks that bring these relations and interactions to light.¹⁰ For some authors, extreme weather events or outbreaks of new viruses, for example, indicate networked interactions spanning the globe, revealing contingent linkages, interconnections and feedback loops (see, for example, Haraway 2015; Tsing 2015: pp. 37–43; Gillings 2015).

The ability to see or sense the actual effects of relational interactions becomes more enabling, the more connections can be established or imagined across greater distances and across more varied forms of interactive life. These complex and intricate feedback loops also call for greater technological capacities. Thus, these tasks can be accomplished, according to Latour:

... by crisscrossing their [the loops'] potential paths with as many instruments as possible to have a chance of detecting in what ways they are connected ... laying down the networks of equipment that render the consequences of action visible to all the various agencies that do the acting ... '[S]ensitivity' is a term that applies to all the agencies able to spread their loops further and to feel the consequences of what they do come back to haunt them ... but only as long and as far that it [humanity] is fully equipped with enough sensors to feel the feedbacks. (Latour 2013, p. 96)

Latour's framework sees the ability to sense effects as crucial to revealing the unseen and unknown interconnections of the Anthropocene, involving the technology and regulatory mechanisms necessary to "trace and ceaselessly retrace again the lines made by all those loops" with a "strong injunction: keep the loop traceable and publicly visible" so that "whatever is reacting to your actions, loop after loop ... weighs on you as a force to be taken into account" (Latour 2013, p. 135).

New sensory forms of governance are given a material political form as a new set of political competencies and responsibilities are established: "Such an accumulation of *responses* requires a responsible agency to which you, yourself, have to become in turn *responsible*" (Latour 2013: p. 96). Unlike earlier modes of governance, sensing governance does not seek to make

10. Latour 2013, pp. 94–5; see also, Connolly 2013; Bennett 2010. Latour echoes Connolly and Bennett on the cultivation of sensitivity: "To become sensitive, that is to feel responsible, and thus to make the loops feedback on our own action, we need, by a set of totally artificial operations, to place ourselves *as if we were* at the End of Time." (2013, p. 112; emphasis in original).

causal claims;¹¹ the emergence of effects can be traced to reveal new relations of interaction and new agencies or actants to be taken into account but there is no assumption that effects can be understood and manipulated or governed through transcendental policy goals.¹² Real time responsive forms of management through sensing increasingly focus on the “what is” (Latour 2013, p. 126) of the world in its complex and plural emergence.

The fact that the “what is-ness” of the world is not a concern with a modernist ontology of being and causation is often neglected in considerations of sensing as politics by other means, so it will be considered here and in more detail in the following section. Latour, in the “Facing Gaia” lectures, argues that nature has to be understood in “post-epistemological” terms (Latour 2013, p. 26). By this he means that modernist forms of representation, reduction, abstraction and exclusion cannot know a world that is plural, lively and interactive. This is post-epistemological because knowledge can no longer be extracted from its concrete context of interaction in time and space. In this framing, knowledge, to be “objective”—to be real—has to be plural, fluid and concrete (Latour 2013, p. 49). This is very similar to Donna Haraway’s understanding of “situated epistemology,” which rejects modernist drives to extract knowledge, i.e. to turn knowing into abstractions from real emergent processes through methods of scaling up, generalizing and universalizing; fixing knowledge apart from its plural, changing and overlapping context of meaning (Haraway 1988). In this way of rethinking knowledge, the modernist divisions between subjective and objective and qualitative and quantitative are dissolved (see further, Venturini and Latour 2010).

Latour’s is a flat ontology, where speed, size and scale are momentary and contingent products of interaction rather than constructing and shaping path-dependencies. As Latour repeats, in a world of unknowable contingencies “it is the *what is* that obstinately requests *its due*” (Latour 2013, p. 126). In sensing governance, the focus on empirical analysis to facilitate real time responsiveness enables emergent effects to discursively

11. As Gilles Deleuze and Felix Guattari note, tracing causal chains could only be a “selective,” “artificial,” and “restrictive” procedure, “overcoding” and reproducing its starting assumptions in a transcendent manner (2014, pp. 11–22).

12. Deleuze (1988, p. 128) nicely captures the difference between transcendent and immanent approaches in his suggestion that transcendent approaches introduce a “dimension supplementary to the dimensions of the given, i.e., ideas of goals, direction and causal connections, which separate the human subject from the object of governance. Whereas, on the plane of immanence: “There is no longer a subject, but only individuating affective states of an anonymous force. Here [governance] is concerned only with motions and rests, with dynamic affective charges. It will be perceived with that which it makes perceptible to us, as we proceed.”

frame the tasks and goals of governance. These tasks are now imagined as set by the world itself—and accessed through the development of new mechanisms and techniques sensitized and responsive to the world in its emergence. The post-epistemological implications of frameworks of sensing governance seem to underlie the fascination with Big Data approaches as a way of generating increasingly sensitive real-time responses to emergent effects (see, for example, Mayer-Schönberger and Cukier 2013; Kitchin 2014).

3. Big Data, Objects and Relations

As already intimated in the consideration of Latour's work in the previous section, sensing governance can be usefully engaged with as politics by other means, in that it necessarily shares the ontopolitical assumptions of actor network theory (ANT) and can be informed by a consideration of the long-running engagement between Bruno Latour (the leading proponent of ANT) and Graham Harman (a leading speculative realist) over the conceptualization of this approach (see Latour et al. 2011). Harman takes Latour to task precisely for the actualism at the heart of the ANT approach, stating that, for Latour, momentary relations are more important than the substance of entities (or actants).

For Latour an actant is always an event, and events are always completely specific: "everything happens only once, and at one place." An actant ... is always completely deployed in the world, fully implicated in the sum of its dealings at any given moment. Unlike a substance, an actant is not distinct from its qualities, since for Latour this would imply an indefensible featureless lump lying beneath its tangible properties ... And unlike a substance, actants are not different from their relations. Indeed, Latour's central thesis is that an actor is its relations. All features of an object belong to it; everything happens only once, at one time, in one place (Harman 2009, p. 17).

This focus on relations in the actual, in the present rather than on the potential, or possibilities, which may lie latent or virtual in entities, ecosystems or assemblages, is crucial to the distinction with a causal ontology:

Since Latour is committed to a model of actants fully deployed in alliances with nothing held in reserve, he cannot concede any slumbering potency lying in the things that is currently unexpressed. To view a thing in terms of potential is to grant it something beyond its current status as a fully specific event (Harman 2009, p. 28).

As Harman argues, "Latour is the ultimate philosopher of relations" and in this way inverts the assemblage theory of DeLanda (Harman 2010, p. 176), which understands assemblages as never fully actualized, enabling

the possibility for causal interactions to bring forward alternative paths of emergence. For Harman, and object-oriented ontologists, ANT falls down for its lack of distinction between objects and their relations, which he argues acts by “flattening everything out too much, so that everything is just on the level of its manifestation,” and therefore, the approach “can’t explain the change of the things” or the hidden potential of alternative outcomes (Latour et al. 2011, p. 95). For actor network theory the emergence of new aspects of reality is not a matter of causal depth but of seeing what actually exists but is consigned to the background. As Latour argues:

I call this background *plasma*, namely that which is not yet formatted, not yet measured, not yet socialized, not yet engaged in metrological chains, and not yet covered, surveyed, mobilized, or subjectified. How big is it? Take a map of London and imagine that the social world visited so far occupies no more room than the subway. The plasma would be the rest of London, all its buildings, inhabitants, climates, plants, cats, palaces, horse guards ... [Sociologists] were right to look for “something hidden behind,” but it’s neither behind nor especially hidden. It’s *in between* and not made of social stuff. It is not hidden, simply *unknown*. It resembles a vast hinterland providing the resources for every single course of action to be fulfilled, much like the countryside for the urban dweller, much like the missing masses for a cosmologist trying to balance out the weight of the universe (Latour 2005, p. 244, emphasis in original).

In ANT, as an alternative science of relationality, what is missing in terms of governmental understanding is not relational depth but relationality on the surface: the presence of actual relations which give entities and systems their coherence or weight in the present moment. Thus, for ANT, modernist understandings of the world, whether those of natural or of social science, give too much credence to entities as if they have fixed essences (allowing causal relations) rather than shifting relations to other actants:

The world is not a solid continent of facts sprinkled by a few lakes of uncertainties, but a vast ocean of uncertainties speckled by a few islands of calibrated and stabilized forms ... Do we really know that little? We know even less. Paradoxically, this “astronomical” ignorance explains a lot of things. Why do fierce armies disappear in a week? Why do whole empires like the Soviet one vanish in a few months? Why do companies who cover the world go bankrupt after their quarterly report? (Latour 2005, p. 245)

In February 2008, Latour and Harman participated in a public seminar at the LSE, in which the differences between what are heuristically described

here as the assumptions of the possibility of politics by other means—of sensing governance—were brought to the surface. Noortje Marres made some useful interventions regarding the importance of ANT for the discovery of new ways of seeing agency in the world on the pragmatic basis of effect rather than a concern for emergent causation: “because pragmatists are not contemplative metaphysicians, because they say ‘we will not decide in advance what the world is made up of’, this is why they go with this weak signal of the effect. Because that is the only way to get to a new object, an object that is not yet met nor defined” (Latour et al. 2011, p. 62). Marres argued that taking “as our starting point stuff that is happening” was a way of “suspending” or of “undoing” ontology, in order to study change (Latour et al. 2011, p. 89). This aspect is vital to sensing governance, as this enables a focus upon the surface appearances of change, which are not considered so important in an ontology of causality:

It’s about saying that we have a world where continuously new entities are added to the range of existing entities, everything continually changes and yet in this modern technological world everything stays the same. We have stabilized regimes ... But if we engage in studying specific objects, we do not find this singularized thing that is well put-together, as an object. We do not find it at the foundation but we find it as an emergent effect. (Latour et al. 2011, pp. 90–1)

Surface appearances of things are continually changing as their relationships do, not through an ontology of depth but through networks and interactions on the surface: in plain sight. As Latour states, regarding the “plasma” or the “missing masses” of ANT: “it’s not the unformatted that’s the difficulty here. It’s what is in between the formatting. Maybe this is not a very good metaphor. But it’s a very, very different landscape, once the background and foreground have been reversed.” (Latour et al. 2011, p. 84)

Thus, my argument here is that the political assumptions of sensing governance can be usefully grasped in terms of actor network theory in that the concern is not the nature of systems or substances but ways in which change can be detected through seeing processes of emergence as relational. Relational processes without a conception of depth are co-relational rather than causal as the processes of relation may be contingent and separate conjunctions. The fact that all forms of being are co-relational means that new opportunities arise to see with and through these relations and co-dependencies: whether it is the co-relation of pines and matsutake mushrooms (mobilized by Anna Tsing 2015, p. 176) or the co-relation between sunny weather and purchases of barbecue equipment or the

co-relation between Google search terms and flu outbreaks (Madrigal 2014). These are relations of effects rather than of causation, when some entities or processes have an effect on others they can be seen as networked or assembled but they have no relation of immanent or linear causation, which can be mapped and reproduced or intervened in.

The co-relational rather than causal aspect of actor network theory distinguishes it from assemblage theory or the neo-institutional or ecosystem approaches with their ontology of causal depth (see, for example, the “panarchy” of nested adaptive cycles developed by Gunderson and Holling (2002) or the bottom-up framework of assemblage theory as developed by DeLanda (2006). Actor network approaches therefore lack the temporal and spatial boundedness of assemblages or of nested adaptive systems and have no assumptions of iterative interactions producing state changes to higher levels of complex ordering.¹³ They say nothing of ontology or of the essences of things, merely focusing on the transmission of effects at particular moments; thus they can draw together litanies of actors and actants—the plasma, or missing masses—crucial for describing or understanding how change occurs in systems or states. Suspending or undoing ontology opens ANT approaches to the world of interaction in the actual, or brings the open-ended processual understanding of the virtual into the actual. New actors or agencies are those brought into being or into relation to explain “effects” and to see processes of emergence through “co-relation”. In this respect, new technological advances, driving algorithmic machine learning, Big Data capabilities and the Internet of Things, seem perfectly timed to enable sensing governance.

4. The Rise of Sensing Machines

Human-non-human assemblages of sensors enable new forms of responsiveness but the advancements are not to do with causal knowledge but with the capacities to see through the breaking down of processes via the development of “sensing machines.” I use the term sensing machines to distinguish sensing governance as a very distinct paradigm in contra distinction to causal ontologies of depth and immanence. “Machines” is used although the task performed is similar to that of the epistemic “engines” referred to by Patrick Carroll-Burke (2001, 2006) or the inscription “devices,” Latour deploys, also enabling the invisible to become visible through its traces (for

13. Harman calls this “occasionalism” and argues that Latour provides the first known example of “secular occasionalism” (2009, p. 228) where there is no fixed way of explaining causation or the continuity of events. In ANT, nothing follows from anything else: “Nothing is by itself either reducible or irreducible to anything else” (Latour 1993b, p. 169). The work of composing relations begins again “every morning” (Latour et al. 2011, p. 76). Regarding complexity theory, see Chandler 2014a.

example, Latour 1983). The development of sensing machines is not new to the Anthropocene but is part-and-parcel of the extension of human agency through the use of artificial prostheses to enable sensing the environment. Perhaps the classic example, provided by Merleau-Ponty's work on the phenomenology of perception, would be the walking stick, which enables a blind person to sense the obstacles around them, through the resistance to touch and the sounds made, etc. (Merleau-Ponty 1989) Another example would be the deployment of canaries as sensors for carbon monoxide in mineshafts.

Human, non-human, and technological aids thus have long histories in enabling the extension of human responsivity to effects, through the power of co-relation or correlation. It is important to illustrate why this is correlation and not causation, as this is key to sensing governance. Sensing governance relies on causal laws or regularities, but the key aspect is that they are secondary to correlation rather than primary. As Latour would argue, the key concerns are not ontological but relational: the causal becomes background to the relational foreground. Take the example of the canary in the mineshaft. The precondition for the canary signaling the existence of carbon monoxide is the causal regularity of poisonous gas killing the canary before mine workers are aware of its existence and prone to its effects. However, the problem of carbon monoxide is not addressed at the level of causation (predicting it or preventing it from appearing or solving the problem afterwards) but through developing a method of signaling the existence of poisonous fumes and of increasing human sense-ability through the power of correlation. The canary is a non-human correlational machine for signaling the existence of carbon monoxide. The canary enables the unseen to be seen: it brings the "missing masses", which exist in the mineshaft, into perception. The addition of the canary into the situational context reveals the existence of other actants, the poisonous gases, which were there but previously operated unseen.

Two everyday examples, which draw out more clearly the "machinic" nature of artificial prosthetics for sensing governance are the development of the thermometer and the compass. Both the thermometer and the compass enable the extension of human sensitivity and agency. The prosthetic support they provide is correlational although based upon causal laws or regularities. The compass, based originally on the magnetic qualities of the naturally occurring mineral magnetite or lodestone, can enable a magnetized needle to point a course in relation to the geomagnetic north pole. Thus, mariners could see or sense their direction through the power of the compass as a "sensing machine," enabling new "actants" (magnetic fields of attraction) to be enrolled in navigation through their correlational effects (Dill 2003).

The story of the thermometer is similar; it relies on causal relations, the thermal expansion of solids or liquids, such as water, alcohol and mercury, with the increase in temperatures. These thermal properties of expansion were known to the ancient Greeks and applied or machinized in the eighteenth century with the Fahrenheit scale (Radford 2003). A thermometer is an artificially constructed sensing machine that enables the seeing or sensing of atmospheric changes that would otherwise be unseen. New correlational machines are being developed all the time, enabled by a variety of new technologies, for example, more accurate quantum thermometers, measuring thermal changes at the quantum level. New actants, in this case, intrinsic quantum motions, can be enrolled to create new machinic prostheses for seeing changes in temperature at ever more precise levels (NIST 2016).

Sensing machines have proliferated under sensing governance enabling new high-tech assemblages involving the extensive use of new sensing technologies, often termed “the Internet of Things,” where sensors can be connected to the internet and provide real time detection of changes in air and water quality, earth tremors, or parking capacity etc. The potential use of sensing technologies is extensive. At the MIT Senseable City Lab, for example, researchers informed me of work being carried out using robotic sensors in sewers tracking minute quantities of bio-chemical material. Potentially, local authorities could receive real time information on localized health profiles and illegal drug use.¹⁴ If sewers can be turned into key information generators for bio-sensing and drug and health profiling, it is clear that new forms of sensing governing can provide a whole range of new avenues for monitoring and regulatory policing.¹⁵ Thus new assemblages are being artificially constructed that enable new actants to be enrolled in governance, including non-human and non-living actants, and in doing so, changes can be seen or sensed and therefore responded to, often revealing new threats or dangers or expanding human sensitivity to existing ones.

While these “more-than-human” machinic assemblages are constructed on the basis of causal laws and regularities their purpose is a correlational one: seeing what exists in the present, in the actual, but is unknown or unseen. To take one contemporary example of new forms of sensing governance, Elizabeth Johnson has done insightful work on more-than-human forms of governance in her analysis of the work of commercial biosensing and the use of organic life to monitor fresh and marine water sources for pollution (Johnson 2017). Here an array of animal species, small fish, worms, mollusks, crustaceans, and micro-organisms are monitored intensively to discover their

14. As Charlotte Heath-Kelly (2016) notes, big data ontologies of complexity lead to universal rather than targeted surveillance parameters.

15. Personal interview, researcher, Senseable City Lab, Massachusetts Institute of Technology, 30 March, 2017.

norms of functionality and to develop ways of measuring changes in these indicators. They are then ready for use as sensing machines:

[The company] monitors a suite of “behavioral fingerprints” as these organisms are exposed to different systems. Locomotor activity, reproductive rates, and embryonic developments are measured together to indicate the severity of hazardous anthropogenic chemicals as well as biologically produced toxins, such as blue-green algae. In this way the company boasts, it can make “pollution measurable.” (Johnson 2017, p. 284)

As Johnson notes, sensing governance is less about causation than seeing the unseen: “making imperceptible harms perceptible” (Johnson 2017, p. 284). This approach sees through correlation, which enables new problems and possibilities to be detected. For example, changes in the bodily indicators of the animal organs can alert human agents to identify potential problems even if the sources are unknown. Thus, the company concerned argues that problems can be detected “in due time before pollution irreversibly spreads in the environment or even harms human health” (Johnson 2017, p. 284). In a technological extension of the non-human prosthesis of the canary down a coalmine, “biosensing enables a way of seeing with nonhuman life” (Johnson 2017, p. 284).

Just as for the thermometer to work as a sensing machine the properties of mercury needed to be understood for its enrolment, for biosensing technologies, green fluorescent protein (GFP) has been a widely used tool to enable organic life to be modified into sensing machines, potentially signaling a wide range of changes in acidity and alkalinity as well as the presence of pathogens, toxins, and cancer causing agents (Johnson 2017, p. 285). Sensing governance, on the basis of developing new forms of correlational sight, enables a fundamental shift from governance on the basis of “problem-solving” and analysis of “root causes” to the governance of effects. In this way of doing politics by other means, distinctions between scientific disciplines and individual entities tend to disappear as these historically depended upon organic conceptions of causation. In contrast, the politics informing sensing governance is not concerned with entities or with causation, enabling “more-than-human” assemblages of responsivity to become the new governmental norm.¹⁶

16. This form of governance through the modulation of effects can be usefully grasped in terms of Deleuze and Guattari’s concept of “machinic enslavement,” derived from cybernetics, where responses are automated to manage or govern on the basis of maintaining equilibrium. In this process there is no distinction between using a machine and being part of the informational input to the machinic process: the process itself is more important than distinctions between entities or individuals (see Deleuze and Guattari 2014, pp. 531–36; Lazzarato 2014, pp. 23–34).

5. Conclusion

Sensing governance is less concerned with adaptive change (to prevent problems before they occur or with transformation afterwards) than with responsiveness to problems understood as emergent effects. Responsiveness, in resilience discourses, is increasingly seen as a real time necessity: living with and being sensitive to problems and threats is understood to be the best way of ameliorating their impact (Evans and Reid 2014). Sensing governance thus appears to have a lot in common with Deleuze's conceptualization of a "control society," where time is held constant: instead of a before (prevention) or an after (reaction) there is the continual modulation of responsiveness, an "endless postponement" of a problem (Deleuze 1995, p. 179). The essence of entities, be they systems, societies or individuals becomes much less important than the emergent appearance of surface "effects," which are to be modulated and responded to.

This is usefully highlighted in Stephanie Wakefield and Bruce Braun's recent work on the deployment of "green infrastructure," relying on the agency of nonhuman actors, such as the deployment of oysters as seawall infrastructure, enabling sensing, grounded on the politics of responsivity rather than adaptation (Wakefield and Braun 2018). Thus, non-human life is managed as a way of securing human life. The "oysterecture" approach fits excellently with the politics of sensing governance, laid out here, as it seeks to respond to rather than adapt to climate change. The responsive approach does not concern causation but correlation in terms of changing in response to sea level rises. Most importantly, Wakefield and Braun highlight the distinctiveness of sensing governance, in that rather than seeking to adapt and learn on the basis of causal relations, oriented towards the future, sensing governance has a very different temporality or approach to the future in that it seeks to "*ward it off*," attempting to keep everything as it is by "cancelling out or absorbing events" (Wakefield and Braun 2018; emphasis in original). Rather than seeking to reform or adapt existing modes of infrastructure, sensing governance seeks to maintain existing forms of infrastructure but to add other forms of sensing and responsivity. While modernist or causal understandings had a hierarchy of centralized reporting and adaptation, sensing governance has a much flatter ontology of self-generated responses, whether at the level of society, community, or the quantified self.

Thus, with sensing governance, there is no longer a "line" of causality but a "plane" of relationality—this shift is fundamental in terms of governance, which, as analyzed above, no longer needs to assume a normative horizon or normative goals external to the actuality of the world. However, the rise of sensing as politics by other means is problematic, leaving no room for democratic discussion and debate. As Agamben has highlighted,

sensing governance, focusing on effects, can be seen to be thoroughly depoliticizing, as the tasks of governance are discursively derived “empirically” from the world, rather than from human actors as subjects.

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