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After Numbers? Innovations in Science and Technology Studies' Analytics of Numbers and Numbering

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Locating studies of numbers in STS – and the proposed position of this SI

Number studies have featured often in past STS scholarship. Indeed, one might articulate a history of STS analytic concepts and theories by tracking number studies. One might begin such an undertaking by pointing out that studies in STS followed anthropology in proposing numbers as social entities, noting that in anthropology number studies have featured since the end of the nineteenth century. When STS studies generally were focussing on epistemology, the analytic framings of number scholarship in STS reflected that. From the 1970s until the end of the century number studies proliferated. In line with other areas of STS, a focus on ontology began to appear in number studies in the mid 1990s, albeit at first hesitantly (Watson, 1990; Watson-Verran, 1995). But it was not the STS past with its range of number studies that interested us when we set out to assemble this special issue of *Science & Technology Studies*. We were more interested to show how contemporary number studies were deploying new analytics that are emerging in STS. To this end we were concerned to have contributors reflect on the analytic framing they were using to make their STS number study and to comparatively articulate the analytic affordances it offered. In beginning we register our delighted surprise at how this special issue turned out, noting how much we learned along the way from the authors who have contributed.

We offer six papers each of which we see as broaching a novel issue in STS number studies. They attend to a very wide range of sociotechnical situations where numbers and/or algorithms feature. The nexus numbers and/as algorithms is puzzlingly relevant to taking on numbers. Recognising that numbers both are and are not algorithms (and vice versa) we begin by making clear how we see relations between numbers and algorithms. While algorithms mobilise a protocol that elaborates how to work relations between numbers, e.g. embedded in a database, numbers express a protocol that lays out how to work relations embedded within a number as it comes into being in the banal routines of enumeration, as for example in Watson (1990). Seeing things

this way algorithming is a form of numbering and vice versa, albeit that different sociotechnical means are mobilised. There are of course interestingly different sociotechnical characteristics associated with utilising analogue means (cognitive, linguistic and graphic resources) in banal enumeration, and in contriving enumerated value using digital computation. As we see it, whether analysis assumes in beginning that algorithms and numbers are the same, or that they are different, is contingent on analytic method and questions being asked. This nexus serves as a guide into and beyond this collection. Here it is a preface to our contributions' take on numbers; and in the penultimate section this nexus leads to the notion of 'after' numbers.

A commitment to what might be called 'practices theory' unites the contributions in our collection, we propose, although not necessarily identified as such by our authors. Narration of numbering processes, a strategy common to the papers collected here, expresses this. We see practices theory as particularising, relational, and monistic, and include actor-network theory (ANT) and material semiotics, along with other ontologically focussed empirical studies in this. While many social scientists might consider 'practices theory' as a subset of 'practice theory', we do not go along with that. Rather we see 'practices theory' and 'practice theory' as ends of an analytic continuum expressing differing notions of practices: as achieved empirical regularities on the one hand, and as prescriptively normative on the other (Rouse, 2001). Specifying this sort of separation helps to articulate what we see our collection of papers offers. But whilst we suspect STS would profit from exploring its relations to approaches along this continuum, we turn to recent developments in STS numbers studies. First, we note that ours is the fifth social sciences collection, intersecting with STS, with a focus on numbers and numbering to emerge in this decade. We briefly survey the others to offer an overview of number studies in the social sciences, and to locate our collection within that landscape.

In 2010, *Anthropological Theory* published a wide ranging collection of papers that had originally been presented to a workshop with the title 'Number as Inventive Frontier: Equivalence, Accounting, Calculation' facilitated by Jane Guyer et al. (2010). Noting that despite "number be[ing] seen as a foundational cognitive process, a component of all of social life, a convergent and/or transcendent human phenomenon […] by 1990s socio-cultural anthropology [of numbers] boasted only one major book" (Guyer et al., 2010: 36), the collection set out to attend to at least some of the world's "number-grammars [and] current number regimes" noting that these "do not necessarily have the same properties as each other nor work according to established mathematical theory nor resonate similarly across meaning domains" (Guyer et al., 2010: 37). Given the "complexity of numbers-in-practice" it was seen as "an extraordinarily difficult challenge to meet ethnographically", so it was seen as important to not underestimate "the magnitude of the intellectual challenge of thinking about multiplicity, convergence and divergence in number usage and its grammars" (Guyer et al., 2010: 38-39).

Sociologists Lisa Adkins and Celia Lury gathered numbers studies together under the title 'Measure and Value' in a volume published by *Sociological Review Monographs* in 2012. Among the eight papers were studies of valuation, data, and metricisation, and perhaps giving a clue about the origins of the volume, finally a paper concerned about 'Measure, Value, and Current Crises of Sociology' (Gane, 2012). Shortly afterwards, Celia Lury, teaming up with Sophie Day and Nina Wakeford, published 'Number ecologies: numbers and numbering practices' in *Distinktion: Scandinavian Journal of Social Theory* (Day et al., 2014). This collection set out from the reading of earlier studies "consider[ing] numbers in terms of what numbering *does*, rather than what numbering *is*" (Day et al., 2014: 123). To approach the latter, they asked "how we live *with* or *in* numbers" (Day et al., 2014: 123). To organise the contributions to their issue, they turned to ecologising numbers and analysing them as composed, recognising that different ways of participating in numbers are possible. In short, the issues addresses, "how numbers participate in ecologies" (Day et al., 2014: 127). The specific contributions address percentages, different ways of multiplying, reasoning via algorithms, algorithms of an evaluation score, sensors, arts' engagement with number.

Most recently a collection of number studies published in *Science in Culture*, under the title 'Counting on Nature', edited by Kristoffer Whitney and Melanie Kiechle (2017), sought to investigate the role of numbers in society. These authors saw themselves as asking a new set of questions, and as eschewing hopes that the collected papers might answer deep questions about the quantification of humans and their environments, they sought to make available some answers regarding the shifting constellations of authority, expertise, and narratives in contemporary culture. Among other questions they asked

> Who quantifies, and to what purpose? Are numbers merely fact and/or rhetoric, or are they available as meaningful bodily experiences and stories about the past, present, and future? How do conflicting social forces attempt to make different meanings from numbers? How does the practice of quantifying nature differ between corporate, state, and non-state actors? How do narratives and bodies challenge or reinforce the centrality of numbers in understanding, representing, and regulating environments? (Whitney and Kiechle, 2017: 4)

In contrast, as we already stated, in our project we were concerned to find out how contemporary number studies were deploying new analytics that are emerging in STS. Our purpose was to make an investigation of our discipline rather than attend to 'a gap in the discipline' as the anthropologists had sought to do. We did not see ourselves as attending to crises in the discipline, nor as showing the contemporary roles and effects of numbers in society. Further, in making our investigation we had no wish to specify beforehand what we saw as the new analytics emerging in STS. What we offered in our call for papers was a rather vague typology of approaches associated with four analytic clusters. We do not repeat them here, for as it turned out our imagined continuum of approaches was indeed just that. We received a large number of submissions which proposed to evidence the many and varied effects that numbers and numbering have in society. Winnowing out those that actually engaged with simultaneously interrogating numbers and the analytics of that interrogation left us with the six papers that follow. We relate and introduce these papers first, and subsequently turn back to numbers, algorithms and what STS has to gain from simultaneously interrogating numbers and analytics.

Empirical and Analytical Relations

We cluster this special issue's contributions in two sets and identify that one paper (Ingmar Lippert's) connects these two clusters in its pointing to each of the phenomena foregrounded. As we read them, the first two papers, Daniel Neyland's and Martina Klausner's, with their narratives of algorithmic processes, focus upon scenarios that we characterise as 'after numbers'. The phenomenon we point to with this characterisation concerns managing incompatibilities. As ontological phenomena, gaps, non-fits, and mathematically non-cohering processes are glossed over using the aura that hangs about numbers in modern society. Such is the status of pursuits mobilising enumerated entities that something like 'the smell of numbers' can be used to effect clunky connections and work-arounds. This is a form of connecting effected in ignoring. Participants agree to go on as if things connect up, so in the actual happenings of particular times and places they *are* connected. In Neyland's paper we see an algorithm that does not quite do what it is meant to do sent to the market nevertheless. Klausner reveals how emoji kittens on a smart phone screen connect the actions of reluctant children and an algorithm calculating therapeutic effect.

The papers of Tjitske Holtrop, Radhika Gorur, and Catelijne Coopmans work with 'found' numbers. By narrating the 'lives' of their found numbers in various situations, they propose these found numbers, concepts which have been subject to processes of enumeration, as ontologically multiple. In much the same way, Annemarie Mol (2002) proposed the concept of the disease atherosclerosis as found in various corners of a Dutch hospital as bearing an ontological multiplicity. In oscillations of singularity and multiplicity things hold together. Lippert's paper, comparatively juxtaposes two analytic instruments that fall within actor network theory. He shows that Callon and Law offer particular possibilities and Verran offers others. He shows they are not equivalent in what they reveal, but rather are complementary.

In the process of revealing differential strengths of the techniques Lippert shows that ontological multiplicity of numbered entities offers unexpected flexibilities in carbon accounting practices.

As a way into the study of numbers and incompatibilities within numbers, we introduce Daniel Neyland's (2018) study first. Empirically, he focuses on a process of research and development for a privacy technology. The project he followed attempted to construct an algorithm that would go through CCTV data and automatically delete data, a version of smart CCTV (see also Möllers, 2017). To sell this technology as a privacy technology within the wider security market, the technology needed to be demonstrated as an effective technology. At least this is what we might assume. Deletion, as Neyland shows, is not straightforward, neither technically not analytically for the STS scholar. The resolution of that tension, in his story, is provided by the market: it performs commensurability between different ontotechnical orders, which the algorithmic logic resisted to.

To analyse the making of a technology for deletion, Neyland draws on Michel Callon and John Law's (2005) notion of qualculation, which they drew from Franck Cochoy (2009). This analytics allows Neyland to reconstruct the judgements inscribed in the deletion algorithm, separate out objects, classify them and operate on them. Algorithm building turns into qualculative work. However, Neyland argues that qualculation cannot well handle the disruptive figure of deletion and so he turns to Hetherington and Lee (2000) who provide him with the notions of the blank figure and motility. These notions, he concludes, provide useful analytical means to study dissonance within the project of accountably performing deletion.

Commensurability is an overarching theme in Martina Klausner's (2018) contribution, too. Empirically complementing Langstrup et al.'s (2013) paper in *Science & Technology Studies* on the relations between numbers and patients, Klausner is interested in how numbers participate in inferring from and interfering in patients' lives. Klausner's analysis builds on a study of the development of an e-Health technology, a monitoring device that would help patients note the duration of their implementing a prescribed therapeutic strategy. The critical empirical contribution concerns the different modes of calculating and measuring these time periods – where Klausner contrasts patients' practical ways of meaning making and the device's learning algorithms' situated ways of inferring and calculating. Her analysis adds onto Neyland's market a clinical case of performing commensurability.

To differentiate different modes and types of inferences and numbers' relating, Klausner draws on Helen Verran's (2001) and Paul Kockelman's (2017) work. She finds in Verran the capacity to engage numbers' performative properties and their alternative modes of ordering as well as generalising. Kockelman's work serves in Klausner's analysis to consider chains of inferences in computer-generated meaning. Klausner recombines both their capacities to focus on the accomplishment of numbers as robust and durable. Where Kockelman specifically is helpful to differentiate types and modes of inferences, Verran allows Klausner to spell out microworlds that generate numbers and are generated by numbers. Klausner's contribution urges us to detail concrete practices without assuming specific mathematical inferences.

Opening up the mathematical presumptions of a seemingly routine calculation, Ingmar Lippert (2018) leads us into the world-making of an equation. The latter consists merely of one division and one multiplication. However, the situated use and performance of these operations connect different universes, Lippert argues. Commensurability between these is established by bringing into being a hitherto non-existing data-point. To zoom into this performative equation, Lippert utilises the genre of mathematics itself and the reader is guided through the equation's unfolding both with ethnographic detail and with mathematical formula. That the formula is not mathematically coherent is not Lippert's point, but rather it illustrates his investment in tracing the situated logic of the calculation within the office context and what the number was for. Empirically, this number was part and parcel to the construction of a corporate carbon footprint. The calculator's accomplishment is reconstructed as managing incompatibility by ignorance that produces comfort in the face of the mathematical tensions

within the enactment of nature. This links into *Science & Technology Studies*' trajectory of critically exploring numbers and data in constructions of or for neoliberal environments (e.g. Granjou and Walker, 2016; Sullivan, 2018).

To analyse the calculation, Lippert comparatively reads two analytics, Callon and Law (2005) on the one hand qualculation, and Verran (2001) on the other. He coined the phrase 'ontologising troubles' to name Verran's technique. Lippert's analysis performs empirical philosophy as a method in this contribution as a means to present three narrations, of the calculation, of analysing the calculation as a qualculation and of the calculation as ontologising and troubling. By comparing the two analytic narrations, Lippert shows how both are clearly connected, in that they express an actor-network analytic sensibility, but also that they are also usefully differentiated. He identifies in qualculation analytics the capacity to reconstruct a teleologically oriented calculative process that is mathematically agnostic. Lippert characterises the technique of 'ontologising troubles' as enabling to identify how within a number multiple versions of certainty and coherence are achieved despite the mathematical troubles.

Continuing the theme of the simultaneous effects of singularity and multiplicity of a number, Tjitske Holtrop (2018) focuses on the number 6.15%. This number was at the centre in Dutch engagement with the enrolment rate of girls in Afghan schools, specifically international intervention in Uruzgan, a region well known for its links to the Taliban. Holtrop, however, turns to counting and accountability as part of mediating what happens on the Afghan ground and various levels of administration. A spreadsheet emerges as a central device for representing education; yet in turning to the singular number, Holtrop also explores its multiple references. With her analysis of work going into the spreadsheet and work based on it, Holtrop's account contributes to *Science & Technology Studies*' attention to the spreadsheet as a central device for organising and transforming data (see also Goëta and Davis, 2016; Lippert, 2018).

Focusing on 6.15%, Holtrop explores how the number relates to various environments. She proposes the notion interface for the character of a number to relate to an environment in which it is used in some way. This reflects the thrust of work by Verran (2001) and Day et al. (2014), addressing numbers as participants in ecologies of social worlds. Using Callon and Law's (2005) qualculation, she suggests that when numbers relate to an environment, they also transform. However, she returns to Verran (2001) to engage with how numbers' inside contribute and shape the practical engagement with the number. With Verran, Holtrop develops a second level of meaning of interface: Also internally, the number is multiple, Holtrop suggests. She identifies an "oscillation between doubt and certainty, towards stability and chaos" (Holtrop, 2018: 79).

Radhika Gorur (2018) turns to Australia's 'Education Revolution'. With this, like Holtrop, she engages in empirically analysing schools, education and their governance trough numbers – extending earlier work in *Science & Technology Studies'* broad focus on higher education (e.g. Tuunainen and Kantasalmi, 2017). Gorur's focus is on a public website that the state administration deployed to achieve transparency about schools' performance. She is interested in how the numbers presented are calculated and how they reconfigure other parties, including parents and schools. She uses the concept of 'informed publics' by Callon et al. (2009) to address how the government provision of simple calculations to the, thus, reconfigured public enabled the latter to not simply heed the numbers but also to question them.

This questioning of numbers is analytically of central interest to Gorur. She employs specifically Kristin Asdal's (2011) work on the production of non-authority to attend to this mode of relating to numbers. Where Asdal points to the role of intimacy in accounting whereby control was not exercised from the distance but inserted intimately within the controlled office, Gorur indicates how intimate accounting was enabled from the distance, allowing both the governmental numbers to reconfigure intimate relations in schools and families. She shows, too, however, that the informed publics were not relating to these numbers in a singular way, but multiply: publics subverted and refused numbers. She conceptualises these ways of relating as a form of

achieving non-qualculability, with Callon and Law (2005).

Intimately engaging with numbers is also a theme in Catelijne Coopmans' (2018) analysis of multiple ways of respecting numbers in a meeting. Whilst often in a meeting, numbers are presented (e.g. on a screen in a control room, Silvast and Virtanen, 2014) and action is taken based on these, in Coopmans' focus is the question of how accountably presenting, and engaging with, numbers is accomplished. She explores a series of meetings in a Singaporean medical centre in which diagnostic results were presented as part of project that sought to innovate a diagnostic infrastructure. In these meetings, she repeatedly encountered various actors who were quite obviously not satisfied with each other's ways of relating to numbers.

Thus, Coopmans explores how numbers are differently brought to life. She approaches numbers' liveliness specifically through Helen Verran's (2012), Dawn Nafus' (2014) and Tjitske Holtrop's (2018: 75-88) work and uses them to posit "numbers' relational agency in knowledge-practices" (Coopmans, 2018: 112). She then deploys her case as a 'comparison engine' (Beaulieu et al., 2007) to learn about her case as and simultaneously contrast Helen Verran's (2001) take on numbers as unity/plurality, John Law's (1994) 'modes of ordering' and Steve Woolgar and Daniel Neyland's (2013) 'accomplished ontology of entities'. She shows how each of these achieves a different symmetrical analyses of the competing commitments to respecting numbers. To think about this, she suggests the metaphor of the kaleidoscope. Coopmans' analysis concludes, thus, in terms of the kaleidoscope of analytics that organise symmetrical descriptions shaped by different concerns. And these analytics are differently generative of results, revealing different nuances about the analysed material.

Collectively Contributing to Number, Algorithm and Data Studies

The kaleidoscopes employed within this special issue indicate the range of capacities in recent STS analytics of numbers to analyse processes and practices involving numbers. Based on our authors' selection and use of analytical approaches, we identify a core contribution of the SI to STS: Even though many of the approaches share family resemblance, the contributions assembled here, indicate that the approaches effect different analyses. As a retrospective map, we indicate in Figure 1 which contributions to the SI deployed, tested or compared which analytics whilst interrogating numbers.

We suggest, STS has much to gain from papers that simultaneously interrogate a phenomenon, in this case numbers, and analytics. This is a dual interrogation. Whilst STS is well equipped with studies of technoscientific phenomena (first interrogation), being explicit that and how we interpret and reconfigure analytics when producing a narration of the genre 'analysis' (second interrogation) generates three contributions. First, we learn

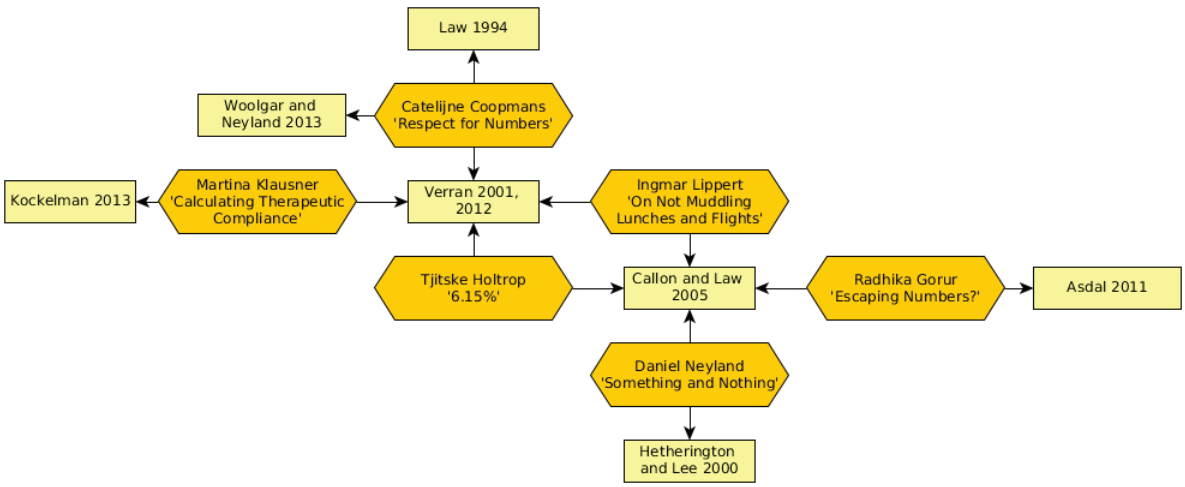

Figure 1. Map of use of core analytical approaches in SI contributions.

about the epistemic configuration of the phenomenon. Second, we learn about the limits and capacities of the analytic. And, third, we render ourselves, our practices of analysing, accountable to the reader, and to ourselves (see Kenney, 2015).

For this special issue we assembled contributions to comparatively interrogate several analytics. By contrasting the capacities and limits of two analytics, a paper can reveal and discuss nuances in STS's own knowledge-making. We assembled papers that show this contrast (Gorur, Holtrop, Neyland) and that discuss the contrast (Coopmans, Klausner, Lippert). The collection of these papers indicates that different modalities within a broad community, like actor-network theorising, produce different results.

Producing accounts that perform not only the dual interrogation – of analysing the phenomena but also the analytics – but also interrogate the differences between several analytics – not as abstract theories or tools but as they are performed in analytic practice – is demanding much of authors as well as of readers. As stories of multiple interrogations, to be generative, the story-telling needs in-built patience that allows for sensing and explicating nuances through which differences, compatibilities or equivalences between specific components and relations built into analytics are accomplished. This multiply interrogative strategy then opens the black boxes of STS's own analytics.

One development, originally surprising us – us being invested in post-ANT analytics of numbers – was that authors used these analytics not only to study numbers, but data and algorithms, too. So we return to the nexus of numbers/algorithms, and extend it to include data.

We recognised early on that it is a common perception among STS scholars that numbers and numbering studies includes algorithm studies as well as data studies. In contemporary technosciences numbers and algorithms and data come tightly knitted nowadays. Each of the projects that have excited the interest of our contributors involved working the relation between these forms. Let us pause and reconsider that seemingly obvious point.

Whilst Helen Verran's (2001) work is concerned with and disconcerted by basic arithmetic practices (e.g. enumerating tomatoes, measuring length), many STS projects engage with with numbers and data within socio-technical contexts that include the processing of a range of data-points or even infrastructures. Consider Paul Edward's (2010: 92–96) presentation of the computers orchestrated to solve an differential equation in 1922: 64,000 human computers were to conduct ordered steps of arithmetics, i.e. perform an algorithm. Whether performed by human or silicon computers, at each step, we are concerned with an algorithm-con-computing entities (multiply by 2), calculating with variables (qualities) and their contents (quantities), step by step.

Two kilogram of tomatoes, when datafied, could be represented as $x = 2$. Where x equals "kilogram of tomatoe". The first step's finding, it's results, the content for the specific variable, is 4. 4 is given as input to the next step, as data. Though, the data storage ideally stores the 4 as the content for the variable x. So, data includes not just the quantitative meaning, but the qualitative, too. Decisive for the semantic load of the variable, Ingmar Lippert (2013, 2018) points out, two qualities are involved, the standardised unit kilogram and the qualitative category of tomatoes. Helen Verran's (2012) chapter 'Number' engages this semantic complex with the term 'number'. Lippert (2013: 93) illustrates the (un)certainty potential of such a number with a triangle, indicating that for mathematical coherence all of the three components and their relations need to be under control. Managing this control is labour (Coopmans, Lippert).

In technoscience, corporate or political contexts, performing data, and big data, comes with a risk; a risk also for STS analyses: ignoring relevant issues within these semantic knots. Inside numbers we might find mathematical non-coherence, or more complex socio-cultural investments.

The contributions to this special issue can be read as showing multiplicity both within the doing of numbers (Klausner, Lippert), outside (Gorur, Neyland) and where the inside and outside collapses (Coopmans, Holtrop). So, numbers can be studied as networks, their inside explored, what is behind them. This implies analysing number as relational practice. And we can study how numbers are used, contested, including the

contestation of how numbers should be engaged with. Therefore we suggest numbers as sites of the political that precedes numbers' social effects – social effects that STS and related fields have proven already to be worth of scrutiny.

This special issue shows, too, that human actors, and potentially artificial actors, too, are partially well aware of tensions and frictions within their numbers, data or algorithms (Lippert, Neyland). To be sure, this implies specific ontologies and analytics, held by members 'in the field' themselves, are employed by members to evaluate their numbers, data or algorithms.[1] We consider it a task for the STS scholar to analyse the actual material and epistemic practices that shape numbers and stories of numbers. This then includes interrogating both members' and scholars' analytics through which numbers' harmonies, tensions and frictions are established. In parallel to insisting of the vitality of carefully interrogating our own analytics, we insist on exploring the politics of real-worldly numbers, including of numbers with in-built incompatibilities. Ignorance is only one form of managing incompatibilities, others are corrections and mislead attempts of correction. We identify in the contributions an amazing variety of how numbers, too, are also employed as a guise. Performing numberliness effects relations and connectibility; numbers appear as ready plug-ins (see Latour, 2005). However, we must not forget that numbers can be practically, even if mathematically invalidly, processed in algorithms; recent big data enthusiasm risks multiplying such risks. These may fail science, engineering, markets and democracy (e.g. Lippert, 2016).

After numbers!

Analysing numbers leads us to considering how we analyse numbers. This is a sideways movement. When analysing numbers we are making the analytics work and pass it along. In passing it along, 'it' changes, it is remodalised. This implies that an analytics, a theory, is never isolated or 'pure'. Instead, the analytics is situated – e.g. in a textbook or in a research paper that performs 'applying' it. So we invite attention to how we can exercise care in using and making analytics work. What does it mean to do 'good work' *with* STS number analytics, *through* or *on* them? We register a value in simultaneously interrogating numbers and the STS number analytics: this mutual interrogation qualifies the relations between numbers, analytics and, then necessarily, the analyst. Some of the papers in this collection provide situated responses to these concerns, and we read these as particularly generative for understanding the nuances of analytics and how their interpretative flexibility comes to matter in STS analyses of numbers. In short: going after numbers requires thinking through how we go after them.

'After numbers' captures seven points we like to end this editorial with.

First of all, being somewhat humble, we recognise that the quantitative value of numbers may not be at stake, numbers may be ignored (see also Lampland, 2010). But still, the numberly guise of numbers here can be expected to be decisive.

Second, recognising the significant tradition of studying the social effects of numbers, we suggest that after the fact, after a number has been produced, many relevant phenomena can be studied. Phenomena that employ the number: n^{th} order calculations.

Third, once we encounter a number, we can turn to what happened behind, before, it. Thus, after identifying a number, we turn to its emergence, its becoming-number. Within this process of becoming, significant commitments to the expected number may be invested.

Fourth, from a temporal perspective, engaging with the two prior points gets us onto the track for a study of the life-cycle of the number or a narrative diary of what happens on its multiple and lively ways.

Fifth, numbers are often invoked in discourses of accountability and rational, calculable, action or evidence. Addressing these matters, politically.

Sixth, we can employ STS number analytics in studies of data and algorithms, too. And more conversation, specifically mutual interrogation, between number studies, data studies and algorithm studies may prove valuable.

After Numbers! This is a call to employ, further develop, interrogate STS number analytics and study numbers.

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Notes

1 Mathematics establishes the extreme case, in itself deserving STS attention (Rotman 1999; Heintz, 2000; Barany and MacKenzie, 2014).

Something and Nothing: On Algorithmic Deletion, Accountability and Value

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Abstract

This paper draws on a three year ethnographic study of the development of an algorithmic surveillance system. It explores ways of understanding the doing and undoing, something and nothing of algorithmic video analytics. The paper pursues a means for engaging with something and nothing by initially drawing on treatments of calculation and qualculation to explore doing. It then seeks to broaden out qualculation by drawing in distinct provocations – blank figures and motility – to engage with forms of undoing. The paper uses the ethnographic study of the algorithmic surveillance system as a means to reflect on the analytic utility of this approach. The conclusion considers three points on something and nothing that this project generated and that could be developed further in future research.

Keywords: algorithms, deletion, value, accountability

Introduction

This paper suggests that qualities and quantities can be enacted, bringing realities into being – in conversation with the pivotal issues provoked by the special issue on numbering and numbers (Lippert and Verran, 2018). At the same time, it suggests qualities and quantities can be undone. The paper focuses on the development of an algorithmic surveillance system designed to delete a large percentage of the data on which such systems would normally depend. As we will see, deletion was proposed as a means to ensure privacy. What the paper will explore is the notion that efforts to delete involved both doing – algorithmically selecting data for deletion to bring a new reality of privacy into being – and undoing – the production of a stream of system outputs that continually demonstrated the system's ineffectiveness. In this way, something (data) ought to become nothing (through deletion). But as the system only ever proved partially effective, the new reality of privacy was never more than hesitant and uncertain. The developers of the system also looked to sell the technology to the security market. Hence nothing (deletion) would need to become something (sales). The paper uses the deletion system as a basis for exploring possible ways to engage with this doing and undoing, something and nothing.

Drawing on a three year ethnographic study of the development of the algorithmic surveillance system provides an opportunity to develop and test the analytic utility of drawing together distinct ideas from Science and Technology Studies (STS) on quantification as an initial basis for under-

standing doing and undoing, something and nothing. The paper will pursue an analytic means for engaging something and nothing by initially drawing on treatments of calculation and qualculation to engage with forms of doing. It then seeks to broaden out qualculation by drawing in distinct provocations – blank figures and motility – to engage with forms of undoing. The paper uses the ethnographic study of the algorithmic surveillance system as a means to reflect on the analytic utility of this approach. The conclusion considers three points on something and nothing that this project generated and that could be developed further in future research.

Qualculation and deletion

In order to make sense of doing quantities, one starting point is provided by studies of calculation. STS work on calculation raises a number of challenging questions. These include how accuracy is constructed (MacKenzie, 1993), the accomplishment of numeric objectivity (Porter, 1995), trading, exchange and notions of equivalence (Espeland and Sauder, 2007; MacKenzie, 2009), among many other areas. The kinds of concern articulated in these works is not focused on numbers as an isolated output of calculation. Instead, numbers are considered as part of a series of practical actions involved in, for example, solving a problem (Livingston, 2006), distributing resources, accountabilities or responsibilities for action (Strathern, 2002), governing a country (Mitchell, 2002), and ascertaining a value for some matter (Espeland and Sauder, 2007; MacKenzie, 2009). Verran (2012: 112) suggests that the constitution of a numerical value involves a complex kind of politics that emerges through "a seamless elision of the dual moments of articulating an order so as to create value, and valuing the categories created in the order to stabilize the order". The switch between using numbers as a basis for ordering and as a basis for valuing becomes hidden and hence switching becomes one basis for numbering activities to embody judgements (such as how and when to switch). We might say then that the seamless elision is one of doing both qualities and quantities. This is the starting point for the neologism of qualculation (Cochoy, 2002; Thrift, 2004). For Callon and Law:

> Qualculation implies qualification. Things have to qualify before they can enter a process of qualculation… this can be … done in an endless number of ways. With an endless range of mechanisms and devices. (Callon and Law, 2005: 715)

The work of qualculation, they suggest, operates in three parts:

> First, the relevant entities are sorted out, detached, and displayed within a single space. Note that the space may come in a wide variety of forms or shapes: a sheet of paper, a spreadsheet, a supermarket shelf, or a court of law – all of these and many more are possibilities. Second, those entities are manipulated and transformed. Relations are created between them, again in a range of forms and shapes: movements up and down lines; from one place to another; scrolling; pushing a trolley; summing up the evidence. And, third, a result is extracted. A new entity is produced. A ranking, a sum, a decision. A judgment. … And this new entity corresponds precisely to – is nothing other than – the relations and manipulations that have been performed along the way. (Callon and Law, 2005: 719)

Detachment, forging of new relations and the production of a judged result provides an initial analytic focus for studying the doing of quantification and qualification. These forms of qualculation can be seen at work in recent discussions of algorithms. Defined in relatively benign terms as a basic set of instructions to be put into action through computer code (Goffey, 2008), the algorithm has been subject to research in diverse circumstance, from Google search engines (Gillespie, 2013) to academic plagiarism software (Introna, 2013). Taking the latter as an example, plagiarism software would produce an algorithmic qualculation by detaching strings of characters (words, sentences and so on), forging new relations between those characters and other entities (by searching for similar or identical strings of characters in the world of published texts beyond the string) and producing a qualculative result; a basis for judging the similarity and distinctiveness

of, for example, a student essay and already published texts. The algorithmic qualculation studied by Introna is a commercial product sold to Universities, which uses detachment, forging of new relations and the production of a result to generate a judgement of the students most likely to have plagiarised their essays.

Using algorithms to make judgements (such as who has cheated in an essay) has led to multiple and quite dramatic claims being made regarding algorithms and their likely contemporary consequence. For example, power has been presented as an indisputable feature of the algorithm (Lash, 2007), generating consequences beyond the understanding or control of those subject to such consequences (Beer, 2009; Spring, 2011). The algorithm has been presented as having an inaccessible politics of programming logic (Gillespie, 2013), a kind of politics that might run wild (Slavin, 2011). In this approach, algorithms are attributed power and agency to scrape our data together, detaching it from its conventional moorings, create new associations of classification, and make judgements of our relevance and value. This has led to calls for resistance[1] – we could say that one concern has become how to prevent the algorithm from running wild.[2]

Within the European Union, limiting or resisting data sifting algorithms has taken the form of a twin policy response to pursue the possibility of a right to be forgotten combined with a right to accountability. In other words, a future is imagined in which the algorithm might not only be stopped from running wild, but the expectation is that these stops will be made accountably, demonstrably, even transparently[3] available. First has been the move to articulate and institute a 'right to be forgotten' or 'right to erasure'[4] as a feature of the revision of the EU Data Protection Directive (Directive 95/46/EC).[5] As Bernal (2011: n.p.) highlights the right has become defined as "the right of individuals to have their data no longer processed, and deleted when they are no longer needed for legitimate purposes.". In this sense, the algorithm would be limited in that it could no longer detach data, form new relations or results from data. Second has been a move to establish a basis for accountability. The EU Article 29 Working Party on Data Protection has issued an Accountability Principle which sets out a provision: "to ensure that the principles and obligations set out in the [Data Protection] Directive are complied with and to demonstrate so to supervisory authorities upon request" (Accountability Principle, 2010: 2; also see EDPS, 2010). In this way, the principle of accountability is designed to ensure a transition from Data Protection in theory to practice and to provide the means to assess that this shift has adequately taken place.

Within the development of the new European General Data Protection Regulation (no longer a Directive), these two moves have become entangled such that to delete and thus cut the action through which 'our' data might run algorithmically wild and beyond our control, must also become an accountable feature of activities; organisations must be able to demonstrably prove they have taken on responsibility for deletion and cut 'our' data. It is thus assumed that Data Protection will carry out resistance on behalf of EU citizens.[6] Although the Article 29 Working Party Accountability Principle and the proposed and critiqued revisions of the EU Data Protection Act have been mostly focused on on-line data, these policy moves have also spurred broader discussions of data repositories and data analysis and the posited need for erasure. For example, erasure, forgetting and accountability have become key reference points in the development of what have become termed Privacy Enhancing Technologies (PETs)[7] and Privacy by Design projects.[8] Here the remit for data storage and analysis is not restricted to on-line data but also incorporates concerns with, for example, video-based data, organisational records and forms of policing, among other areas. The premise of these arguments for PETs is that all algorithmic technologies risk running wild with data and might be resisted by technologies which take privacy concerns into account. In these discussions, privacy is often understood in more or less straightforward binary terms. For example, it is proposed that if one's data no longer exists, there is no risk to one's privacy.[9] One type of emerging PET within this field is auto-deletion technologies (also see Mayer Schonberger, 2009). If we accept that these policy discussions and developments are to carry out resistance on our behalf, then to delete and to accountably demon-

strate that deletion has taken place might become the benchmark required for preventing algorithms from running wild (Slavin, 2011) with our data. Deletion might become the means to turn something into nothing (by deleting data) and nothing into something (by rendering deletion accountable).[10]

Deletion and the blank figure

Doing deletion might be open to analytic consideration as a form of qualculation. A conventional approach to deletion involves simply changing the connections through which a user might access data[11]. In this way, data might be selected, new relations formed and a qualculative result – deletion – produced. However, this approach to deleting is unlikely to fulfil the proposed terms of policy mechanisms such as the revised EU Data Protection Regulation or the concerns articulated in the literature on PETs and Privacy by Design. The concern articulated as prompting the right to be forgotten/right to erasure is couched in terms of a need to expunge data from a repository, making it impossible to link, scrape, share or make further user of that data[12]; it is argued that to simply change the route via which information is retrieved can be overcome with little effort and re-opens the data to all future uses[13]. And the Article 29 Working Party accountability principle will require that compliance with such expunging is made clearly and demonstrably available. It involves making absences (deletion) notably and demonstrably present (by making deletion accountable). This kind of something and nothing is not easily addressed through qualculation alone. In place of a seamless elision of quantity and quality are on-going debates as to the feasibility and desirability of this approach. The certainties of doing qualculation appear to be challenged by questions of much undoing.

One starting point for augmenting the notion of qualculation by opening the seamless elision of quality and quantity, doing and undoing, something and nothing is provided by the work of Hetherington and Lee (2000) on zero. They suggest that zero was introduced into western European mathematics and economics in approximately the fourteenth century.[14] Zero provided the basis for a numeric logic of order at the same time as disrupting conventions for ordering, disrupting by connecting otherwise unconnected entities (nothing and the progressive accumulation of something from the number one upwards; as well as at a later date, providing the basis for counting downwards with the introduction of negative numbers to Europe from around the 17th century) and came to be seen as generating a new order. This despite zero itself being an underdetermined figure, both a sign on its own (signifying something of no value) and a meta-sign of order (providing for the significance of subsequent numbers or indicating rank in the decimal system). Hetherington and Lee (2000: 177) suggest that: "What [zero] reveals... is that very basic mathematical ordering practices are themselves dependent on a figure that refuses to adopt a singular position in their semiotic order". Following on from this, we might think of an algorithmic system for deletion not just as a focus for qualculation (doing something), but as a system that refuses to occupy a singular position (both something and nothing, doing and undoing).

However, Hetherington and Lee (2000: 175) go further and suggest that zero, as something and nothing, can also be considered a blank figure, something that: "hybridises presence and absence rather than two forms of different presence". Following from this, an intervention in an order – such as the introduction of zero – can be considered a blank figure when its nature is underdetermined, uncertain, unclear, troubling, provokes tension and generates not just a connection between pre-existing entities, but provides a basis for further investigation of those entities now connected. In this way, an algorithmic system might introduce an accountable nothing (the deletion of data) that would not just create (or remove) connections between entities, but also create new troubling questions (for example, regarding the extent or adequacy or consequences of deletion). Hetherington and Lee (2000) suggest that such disruptive questions can introduce forms of motility, a disruption of the world of relations on which an order might be based. For algorithmic data systems, a motile switching might be provoked in moving from an order based on comprehensive data storage to an

order based on deletion. Whereas studies of qualculation appear to depend on the emergence of a result from a singular order ("a result is extracted"), motility and the blank figure suggest a more persistent instability or multiplicity of order.

In this way, the work of Hetherington and Lee (2000) sensitizes us to the possibility of disruptions to conventions of order through simultaneous somethings and nothings; zero which provides a basis for reordering something (the rules and conventions for order such as negative numbers) and for considering nothing (a more literal zero). Their work also opens up the opportunity to consider motile switching in the world of relations that make up an order. A switch in order might be transformative of both the nature of entities and the world of relations through which those natures have been held steady. The interjection of a new entity (such as zero) might be the basis for such a fundamental switch. Following this argument, to introduce accountable deletion might be to generate a motile switching in the world of relations in focus. The nature of data, of algorithms and their associations might be called into question, and so might the relations that generated the call for accountability in the first place. Instead of algorithms running wild with our data, we might have nothing (deletion), but we might also have a generative something (new accountability relations through which the deletion is demonstrated alongside difficult questions regarding what constitutes adequate deletion). The generative dissonance or profound change in ordering provoked by the blank figure – the something and nothing – as we shall see, attains a brutish presence: the seamless elision of quality and quantity is opened and (at least for a time) held open.

The suggestion that the algorithm can be limited (even through another algorithm), that a new qualculative form can be constituted and inserted into sociomaterial relations, constituting a something and nothing, and that this nothing can be accountably accomplished requires detailed investigation. The empirical analysis will now begin that investigation particularly attuned to the possibility that new algorithms might generate blank figures and motility, disorder as well as order. First, the analysis will explore the creation of an algorithmic system, exploring the ways in which deletion involves active, qualculative work. Second, attempts to accountably demonstrate that nothing has been created from something will be pursued, wherein the certainties of qualculation become overwhelmed by the disruptive figure of what might constitute deletion. Third, the world of relations and motile switches constituted in order to prepare for the accomplishment of value to be generated from the algorithmic deleting machine, will be assessed.

The algorithm at work

The project from which this paper draws was initially conceived as an experimental location for testing out the possibility of creating an algorithmic video-based surveillance system that could take into account aforementioned concerns regarding the prospects of guaranteeing deletion and accountability through a Privacy Enhancing Technology (PET). The suggestion from the co-ordinators at the start of the project was that algorithms could be put to work to create a 'privacy sensitive' surveillance system, but that this could also become a valued commodity. The idea was to monopolise the market space opened up through discussions of PETs and Privacy by Design, the right to erasure and the principle of accountability, by creating and demonstrating a video-based surveillance system that could take on these concerns on behalf of putative end users. Computer scientists from academia and industry, potential end users (including a European train and airport operator) and social scientists (including the author of this paper) were drawn together by the project co-ordinators to work in this experimental space.

In the early months of the project, three principles were constituted as the basis for exploring the development of a 'privacy sensitive' surveillance system. First, that algorithms could be used to detect and select relevant and 'suspicious' behaviour in locations like airports and train stations, and that relevancy could then become the basis for restricting what surveillance operatives got to see, reducing the amount of data made visible in a video-based surveillance system

by around 95-99%. Second, that relevancy selections could then be used to delete the 95-99% of data not required. Third, that new algorithms would not be required for selecting relevance and doing deletion. A 'privacy sensitive' system was thus founded on principles of reduction and deletion, a system which could simultaneously be algorithmic and limit the algorithm. The following analysis will explore the building of the system, attendant attempts at deletion and their consequences.

Building an algorithmic surveillance system

In order for the video-based surveillance system to work, multiple algorithms were drawn together including event detection algorithms for selecting 'suspicious' behaviour and auto-deletion algorithms. These were designed to work in an order; video would be streamed from an existing airport and train station video surveillance system, via a media proxy, which would make available to event detection algorithms, digital video streams to be sifted through to detect such things as abandoned luggage. This was an initial step for restricting the video-based surveillance system: the amount of video-based data made visible to operatives would be reduced by 95 to 99%, using algorithms to make selections of 'suspicious' activities; the bank of monitors common to video-surveillance control rooms would be replaced by a single monitor on which text-based alerts would appear (including text such as 'abandoned luggage alert'); operatives' choices would be constrained to click (or not) on these alerts and a short video clip selected by the algorithm would be played, showing operatives what had set off the alert. In place of the algorithm running wild (Lash, 2007; Beer, 2008; Spring, 2011), there was to be the algorithm constrained; a neat and orderly managed process of generating minimal visibility and clear, bracketed text alerts. Counter to any threat of disorder or motility, the proposed world of algorithmically reduced surveillance appears certain and singular. Yet to produce this orderly world required new forms of qualculation.

Qualculations would work as follows. Event detection algorithms involved a relatively straightforward seeming series of 'IF….THEN' rules. However, prior to IF…THEN rules being implemented, background models of particular spaces such as train stations or airports had to be developed to ascertain the stationary/fixed features of the setting such that any video stream could then be compared to the background to figure out if, and what, was moving. Following Callon and Law (2005), this is the first step toward qualculation – separating out and disentangling entities such that they might be recombined in a single space (within the algorithmic system). The separating out was referred to by computer scientists in the project as a background-subtraction method. Background-subtraction created a 'mask' of pixels covering any entities that were not a feature of the background model already created. Computer scientists used Gaussian mixture models to identify and then 'subtract' from the fixed background these new entities. Further qualification ensued to tidy up the initial 'masks' (which provided approximate shapes of the entities subtracted), with any single, isolated pixels erased and any holes between pixels filled. An extra algorithm and associated code would then remove shadow from the mask, designed just to leave the newly subtracted entity. However, qualculation was more complex than identifying fixed and stable features of a setting and subtracting new entities. It required figuring out a means to classify subtracted things in order to work out just what entities were. Object-classification would attempt an initial definition of what kinds of objects were in view. To figure out, for example, if an item of luggage had been abandoned, required this background-subtraction method for the system to know the fixed and non-fixed attributes of a setting, but also object-classification to know what was a person and what was luggage.

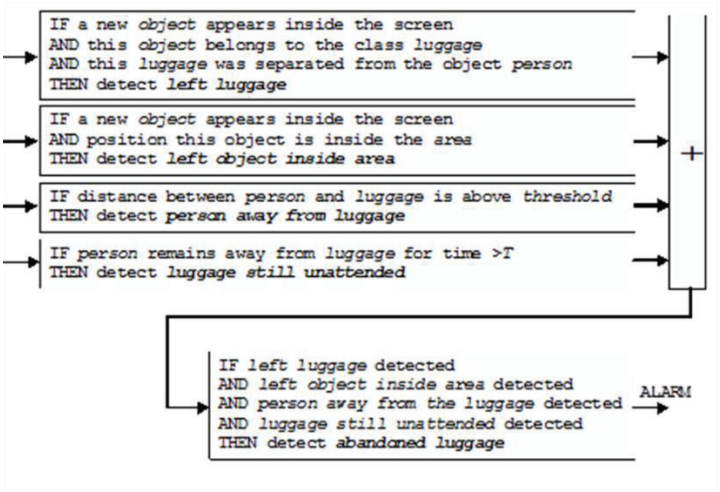
Object classification fulfilled the second feature of qualculation, drawing entities together into new relations such that they might be qualified for judging. Classifying something as a human-shaped object in object-classification involved algorithmic analysis of video streams in order to draw boundaries around 3D models of the likely parameters (size and shape) of human-shaped objects. The same was done for luggage and other items (such as cleaners' trolleys and temporary signposts). And this would provide an initial basis for judgement: some objects (temporary

signposts for example) were designated as things that were not permanent attributes of the setting, but were also not a person or abandoned luggage, and so needed to be classified as non-fixed and non-relevant objects (in this sense, a temporary signpost or cleaner's trolley was classified as a benign object and thus to be ignored). The parameterisation process was designed to cut down on the amount of data the event detection system needed to consider. However, each object was identified through a vector of around 200 features, so each object in itself was complicated.

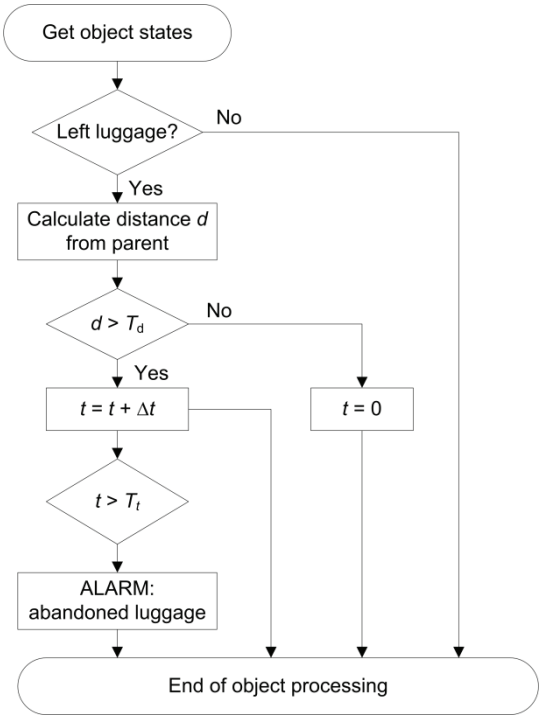
Calculation (using 200 features to assess an object) became a basis for initial automated qualification. One object (possibly a human) and another object (possibly luggage), combined with a known background (such as an airport check-in zone), provided a basis for algorithmically identifying a suspicious scene in potential. However, this was only an initial, approximate judgement. Following object detection via background-subtraction and object-classification through vector analysis, object tracking would take place. The object was given a bounding box based on its dimensions and the speed and direction of the box was noted in its movement across the screen. The bounding box could then be tracked across a camera's visible range and between cameras where the system searched for other bounding boxes of the same dimensions, relative to camera position, angle and zoom. These were termed Tsai calibrations by computer scientists in the project – they did not operate using pixels alone, but rather by working out the position of an object relative to a camera, its position, angle and zoom, and then counting the number of pixels to figure out the dimensions of that object in centimetres relative to its distance and angle from a camera. To calculate the size of an object in centimetres (rather than just its size on a screen), the world of the video stream had to be connected to the world of measurement in the space where the camera was located (such as an airport) and the world of the objects within the video stream had to be connected to the world out there of people, luggage, etc. This was accomplished by measuring the space seen by a camera and then incorporating those measurements into a topological database drawn on by the event detection system. Eleven conversion coefficients including angle and zoom of the camera in relation to the world-out-there measurements[15] were involved in producing an object's size.

This work to produce a more precise calculation also framed the basis for further qualification. Starting from this decision that an object was in a certain position, was of a certain size and so could be classed as a type (for example, a human-shaped object), algorithmic IF…THEN rules could be implemented. These would form the basis for judging initial, probabilistic and hesitant qualifications of who or what was worthy of being seen by operatives (who could then make further judgements – is this a suspicious event, who should be called in response and so on). Qualification through IF…THEN rules could work as follows. For abandoned luggage, IF an object being tracked splits, THEN this could be used to initiate an abandoned luggage alert (on the basis that a single human was statistically unlikely to split in two whilst walking in an airport). However, the IF…THEN rules could also provide the basis for disqualifying an initial, hesitant qualification. For example, IF an object splits and both objects keep moving, it would be less likely to be abandoned luggage or if an object splits and both resultant objects were of the same size, this might be unlikely to be abandoned luggage (in these cases it would be more likely to be a system error whereby two people have for a time walked in synch and then gone their separate ways). The IF…THEN rules needed to accommodate the approximate size of a human-shaped object, IF that split, the approximate size of a luggage-shaped object, IF a luggage-shaped object was not moving, remained at least a specified distance from its human-shaped object and for a specified time, THEN an alert could be sent to human operatives.[16]

Here are the IF…THEN rules for abandoned luggage:



Note here the additions required for an alarm to be sent to operatives. The IF…THEN rules were developed into the following algorithm:



This qualifying work, separating things out, drawing them together into classifications, working through IF…THEN rules to further qualify whether an image needed to be seen by operatives, was directed toward reducing the amount of video-based data made visible. Qualculative work was complex in that it involved detailed efforts to know the space in which the surveillance system operated, build that space into the algorithmic system, and come up with a means to identify and qualify relevant objects. However, this was merely a first step in the move toward limiting the algorithm – identifying relevant scenes, people, objects, and actions. Limiting the algorithm involved using 'relevance' detection as a basis for deletion.

The algorithmic deleting machine

Limiting the algorithm[17] required creating an accountable nothing. In part this involved gathering all the data not seen by operatives along with those clips deemed irrelevant by operatives, and deleting that data. However, it also involved retaining the orderly integrity of the accountability process imagined in relation to the initial qualculation process. Deletion needed to follow a similar logic to that of background-subtraction and object-classification which were expected to be appropriately qualified and made available for accountable judgement. Emphasising the point made by Lippert (2018, this issue), certainty does not precede calculation – instead, calculative practices helped to bring certainty into being. In this project, to generate accountable certainty and avoid motile and disruptive disorderings, the system was designed to work in the following ways. A Secure Erase Module (SEM) would be built of three sub-modules: a secure erasure scheduler (SES); a secure erase agent (SEEA); and a log generator (SELG). The SES would work with the other system components to retrieve data to be deleted

(this would operate using a FIFO queuing system). The SES would send a series of requests for data to the other system components. These requests would include: the full path to the file to be deleted; the start point of deletion (this was based on temporal parameters); and the end point of deletion (using temporal parameters to calculate the final block of video data to be erased in each session).

The SEEA would then work on the data to ensure it was over-written and completely irretrievable from within the system. The basis for doing this over-writing was to try and ensure that data could not be retrieved from within the system and provide accountable certainty for its non-status. In place of conventional deletion whereby data access routes would be cut, over-writing became the basis for expunging data from the system (although in practice this turned into something closer to corrupting than expunging the data as expunging proved technically difficult to automate). The SEEA would then check that deletion was successful by matching the content deleted with that selected by the SES. After deletion, the SELG would then produce a log of data deleted. The log would include the file names of deleted objects, the time taken to delete and the form of overwriting that had been applied. The SELG would act as the key component for producing accountable certainty of absence.

An external viewer component would then parse the log to make it readable by humans and then a human system administrator could audit the log and check it against expectations of how much data should have been deleted (for example by comparing how much data had been deleted against how much data passed through the system on average every 24 hours) and whether any traces had been left (of either video streams or meta data relating to, for example, object-classification). Events which had been the subject of an alert to operatives would be reviewed manually on a regular basis and then also moved into the SEM for deletion as necessary. The audit log provided a basis for demonstrating within the project that deletion was working. As an internal accountability mechanism it could become a means to see that the algorithm was limited, that further qualculations could not be made on the corpus of video-based data that would now be unavailable.

In this sense it might seem that accountability could provide the means to transform nothing (the deleted) into something (proof of deletion) and to do so in an orderly and certain manner. However, the results derived from system testing suggested deletion would be anything but straightforward. In tests carried out 'live' in the airport, designed to act as a demonstration of system capabilities for potential users (airport security operatives), video frames and meta-data were not gathered in their entirety, orphan frames were left behind on the system, and the reporting tool merely produced a continual accountable output of partial failure. Problems particularly appeared during secure auto-deletion; it was in the moment that data should be corrupted and made irretrievable that some data evaded the system's grasp. The computer scientists involved in the project could get the system to auto-delete the system files in their entirety by using an insecure deletion protocol (which effectively shifted deletion back to changing the routes via which data could be accessed) or by dropping auto-deletion and carrying out a manual corruption process (which might prove more complete but also require more work).

Work to build the algorithmic deleting machine and constitute an ordered and certain accountable nothing, a notable absence, instead became the basis for establishing a precarious kind of uncertain presence. Orphan frames and the audit log continually generated a disorderly account of something instead of nothing, a blank figure (Lee and Hetherington, 2000) that paid recognition to the terms of its own order (that it should find and prove the existence of nothing), but also questioned that order (by finding orphan frames that then required explanation). The system threatened to overwhelm the qualculations that had tried to establish a demarcation between data to be kept and data to be deleted.

Hence we could say that as a putative blank figure, the audit log generated a notable question: could the technology still be sold primarily on the basis of its technical efficacy in deleting? The clear and negative answer to this question for the co-ordinators required a motile switching

in the world of relations being built into the system, switching the conditions under which parties might be invited to engage with the system. Initially the project co-ordinators had sought to take the internal accountability mechanisms of deletion out into the world as a basis for bringing the world to the deleting machine. They sought to develop from nothing, a market-valued something. The project co-ordinators sought to leave aside the technical difficulties through which nothing (the deleted) failed to be effectively and accountably constituted, at the same time as they continued to embark on concerted market work. As we will see, having one form of qualculation overwhelmed by this blank figure, encouraged the co-ordinators to seek a different basis for ordering their qualculations.

Market values and deletion

To do market work and build a value for nothing (the deleted), the project co-ordinators had to look beyond accountable outputs of technical certainty (given that the machine had trouble deleting). Instead they looked to build a world into the deletion system through other means.[18] Recognising that the audit log would generate an accountable dissonance, the project co-ordinators introduced a motile switching of the basis on which a world of relations might be built into the technology. From trying to sell technological efficacy, the project co-ordinators instead sought to build alternative relations and hence value through mapping out a new market value for the technology. In line with Gorur's assertion (this issue) that division is required (in Gorur's case between science and politics) to ensure evidential credibility, here a division was drawn up between technical efficacy and the market. In place of technical efficacy as a basis for selling the system, willing customers were constituted as a means to attract others to (potentially) invest in the system. Building a world of (potential) customers to attract investors required a different basis for qualculative work. The world out there needed to be qualified and built into the world in here of algorithmic deletion through an order based on investment. Only through this new basis for qualculation could the seamless elision of quality and quantity be reinstated after it had been opened by the failures of the deletion system.

For the co-ordinators of the project – a European-based consulting firm – the market possibilities of the technology had provided a compelling reason for deletion, algorithmic experimentation and indeed the co-ordination work they carried out over a three-year period. Building a value for the technology following trouble with the deletion system, involved qualculative work to separate out entities such that they might be drawn into new relations (in this case market relations) and become the basis for new outputs (in this case investments). The number of entities involved was broad with market trends, sizes and values separated out and made subject to calculation. For example, the world was segmented by the project co-ordinators into geographical regions to be accorded more value (Central and South America with strong predicted growth rates in video-based surveillance), even more value (Canada and Europe with a growing interest in video-based surveillance and a burgeoning privacy-interested legislature and lobby) or less value (the US with apparently less interest in privacy and a saturated market place for smart video analytics). These segmented geographies were not left as vaguely valued territories, but transformed into specific and precise calculations of Compound Annual Growth Rates (CAGRs) derived from a combination of expensive industry reports the co-ordinators had purchased and on-line sources. In this way, the market for video-based surveillance analysis was calculated to have a CAGR of 15.6% between 2010 and 2016. This was then broken down into the more and less attractive geographical segments previously described.

This provided an initial step in qualculation: geographies were segmented and calculated. However, work to separate and calculate did not end here. Customers were treated in much the same way. Hence governments were identified as a particular type of customer, tied to more or less attractive geographies. The more attractive governments were calculated as accounting for 17.59% of the video surveillance market and as more likely to be compelled into buying a deletion technology in order to promote their own privacy sensitive credentials. Transport was another

customer type segmented and calculated as accounting for a further 11% of the video surveillance market with a predicted CAGR of 13.39% between 2010 and 2016. Major transport-based terror attacks were invoked as a basis for this growth in investment, but transport organisations were also identified as another potentially privacy-concerned customer (this despite the transport companies involved in this project seeming to lose interest in privacy as the project developed). Technologies were also given the same treatment, with pixel numbers, high definition cameras, storage capacity and algorithmic forms of data analysis all separated and calculated as growth areas. Finally video-based surveillance processes such as data storage were also separated out and calculated as a growth area, but with a growing cost – the kind of cost that could be reduced through deletion. Although this separation and calculation work was directed toward qualifying these entities for market relations, the co-ordinators also worked to distinguish entities as outside or external to the world they sought to build into the technology. Hence 44 competitors were also identified, ranked according to size and spend and their particular systems presented in terms of their inferior capabilities in delivering video-based analysis.

Separating out, calculatively preparing and qualifying some entities while disqualifying others (such as competitors) provided the basis for building a key piece of qualculative work for the co-ordinators. Alongside segmented geographies, everything from governments, to pixel numbers[19] became entities of market work. The entities qualified (and disqualified) were drawn together into a world of relations. The world of segmented geographies, customers, technologies, processes and inferior competitors was co-ordinated into a document entitled "The Exploitation Report." Here the qualified (and disqualified) entities made sense as providing a basis for investment. At the centre of the world, however, sat the deleting machine as absence and presence – an investment vehicle whose technical efficacy remained hidden from accounts preventing it from being a somewhat disruptive blank figure (Hetherington and Lee, 2000). Technical capabilities remained notably absent from the Report, rendering the Report's content accountably certain and ordered. The terms of accountability had been subject to an ordered motile switching by the project co-ordinators from proving the system could do deletion to proving there was a market value for deletion. The preparatory qualifications embedded in the Report and the censure of any uncertainty in the terms of accountable proof, would now provide the basis for taking the world built into the deleting machine to a world of investors. Through convincing investors that the Report was compelling proof of the viability of investment and that the deleting machine qualified as a reasonable investment risk, the co-ordinators hoped to also build investors into the world of the machine.

Inclusions, exclusions and careful qualification provided the means for the co-ordinators to try and build a compelling narrative which worked as follows. In place of uncertainty derived from 44 competitors came the assertion that none of the competitors could deliver as sophisticated a solution as that promised by the project. In place of a concern with governments cutting budgets in times of austerity came the assertion that governments must look to cut costs and therefore should look for the kind of cheap storage solutions that auto-deletion technologies could provide. In place of a concern that a new surveillance system might attract privacy-based criticism came the assertion that this system carried with it and provided a response to that privacy criticism. And in place of any concern from among project members that the technology didn't work came nothing; technological inadequacies remained hidden from the Report and its audience. To build something from nothing required this compelling narrative (Simakova and Neyland, 2008) through which particular somethings and nothings could be presented or absented, managing what was made accountably available.

From the preceding analysis it follows that accounts and accountabilities may not be left to fend for themselves, to be orderly or disorderly; accountable order can be a carefully managed activity. Managing motility requires ordering work and concerted efforts. But understanding these efforts requires detailed study of the preparation work carried out in constituting a world of people, things, processes, resources and relationships through which algorithmic deletion might be

accountably accomplished. Preparing a world for deletion involved attempts to produce a notable nothing (the demonstration of deletion) and also the possibility of accumulating something (a different kind of qualculation, a judgement that nothing is available for detachment, for re-inscribing into new relations or from which new results can be produced). This preparation work, however, continued to stumble over the difficulties of deleting and accountably proving deletion had taken place. The doing of qualculation threatened to be overwhelmed by the undoing of the blank figure (the audit log). At the same time, building a machine has costs and requires investments and, it turns out, the careful consideration of future returns on investments for building a deleting machine. The world prepared for accountably accomplishing nothing, then was re-directed toward creating something by demonstrating the value of deletion as an investment proposition rather than a matter of technical efficacy – that a machine could be invested in and might go on to do the work that might be required of the future imagined policies of erasure. Resistance to data sifting algorithms, delegated to the deleting machine might become a marketable good and attain a value. And so we are back to Cochoy (2002) and Callon and Law's (2005) original proposal[20] for qualculation; that it is a matter of qualifying things for market values. In this paper we have explored the work done to prepare a world through which deletion could, and then could not, be accountably accomplished and we explored the work done to prepare and then absent the deleting machine from market-value work.

Conclusion

Through an analysis of one particular project and the work carried out to create a machine to limit the algorithm through deletion, make that deletion accountable and create a market value, this paper has sought to bring three points to readers' attention that might be further explored in understanding qualculations, their doing and undoing. First, doing deletion can be a form of active qualculative work. The members of the project team featured in this paper dedicated hours and effort to build a machine to algorithmically delete. The technical work was also market work and accountability work. It involved co-ordination, computer science, social science, the invocation of end user needs, likely competitors, and different ways to understand a developing policy environment. Doing this work was neither singular nor straightforward, but involved somehow making something from this diverse array. And making something required qualculations to separate out and identify objects, then bring those objects together in object-classifications in order to be judged. Using qualculation in this way provides an opportunity to consider the up-close work of algorithm building. In place of any counter assumption that an algorithm is powerful or will run wild with data, qualculation provides an analytic sensibility for considering the work required to make a numeric and qualitative judgement.

Second, limiting an algorithm is not straightforward; for something to be convincingly limited, it might have to be demonstrably and accountably limited. The work to produce an accountable deleting machine was focused on producing a machine that could account for itself and the way it set limits, demonstrating nothing (the product of deletion) as a prior step to something (the account of nothing, building a world of relations of value into the technology). However, accountability work was also uncertain and a little precarious with the world of relations of people and things assembled to do accountability, shifting between certainty and uncertainty. The study of making deleting externally accountable (outside the project) further emphasised this precariousness – to prove that nothing exists as a result of something being deleted, without resurrecting the thing deleted, proved an on-going conceptual and practical challenge. Technical failure opened the seamless elision of quality and quantity, simultaneously undoing what had been done. On these terms, moves to limit algorithms through deletion require a careful consideration of what is required to render such deletion accountable. We cannot simply move from qualculation, to action, to a straightforward rendering of an account of that action: the actions required to make these steps and the on-going challenges that such steps introduce require attention.

Third, making something of nothing by building a market value for deletion, also involves particular kinds of work. This work was directed toward an ordered and motile switch in the world of relations initially oriented around technical efficacy and subsequently oriented around value (with efficacy subtracted). What might have been something (the details of the technology) became nothing and a new something (a world of relations of value) was generated in its place. Following many weeks of labour by the project co-ordinators in producing "The Exploitation Report", the switch between these worlds of order was hidden. Managing order in this way also transformed a less than accountable something into a market value through qualculative work to segment geographies, technologies, competitors and customers. These were each accorded a calculative value (or non-value) and evidence was amassed from third parties to support the values evidenced. However, market value work was about more than segmentation and calculation-valuation, a disentangling of entities and their reformulation into specific kinds of relationships. The segmented and valued entities also had to be drawn into a compelling narrative that supported the future development of the deleting machine. Work was thus done to connect things we all know are happening now (such as government austerity measures and the need to cut budgets) with features of the technological future (such as deletion), to generate a compelling narrative for investment in the deletion technologies (in this instance that austerity measures and cost-cutting could be achieved through deletion by cutting data storage costs). At the same time, producing a compelling narrative also required that numbers remained hidden that were not to be made accountably available. This continual switching between temporalities – the world as we know it now and the investable future – and accountabilities – things to be made available and things to be concealed – became the means to attempt to compel investors to join the world of relations being built into the deleting machine; that its market value would arrive. This suggests that although qualculation is analytically useful for focusing on how the seamless elision of quality and quantity is produced, the dissonance of the blank figure and motility also provide analytic means to engage with these moments when seamless elision prove elusive. In sum, understanding the doing and undoing of numbers, qualculations, the algorithm and accountabilities, appears to require a developing sensibility for certainty and uncertainty, something and nothing.

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Notes

1 See Gorur in this issue for more on resistance.

2 Except of course to limit an algorithm can require an algorithm

3 Discussion of forgetting, deleting and transparency, involves both positive assertions of the benefits of forgetting the past (for example, an individual who wants old photos removed that they find embarrassing, see: http://www.bbc.co.uk/programmes/b01pnn4m) and cautions of the dangers of forgetting (with, for example, freedom of expression campaigners warning of censorship, see: http://www.bbc.co.uk/news/world-europe-27388289). For more on the challenges of transparency combined with accountability, see Neyland (2007).

4 The discussions have included this change in terminology, although the EU still maintain that a right to erasure incorporates a right to be forgotten: http://www.research-live.com/news/government/eu-civil-liberties-committee-backs-right-to-erasure-of-data/4010672.article

5 This revision partly stems from on-going criticism of the absence of any adequate privacy protection, see for example: Benn and Gauss (1983); Bennett, and Raab (2003); Gallagher (2004); Goold (2009); O' Harrow (2005); Rosen (2001); Rosenberg (1969); Rule (2009); Stalder (2002).

6 Assumed that is by those involved in drafting the Regulation. It is neither clear to what extent the public en mass have called for this resistance nor whether publics would consider this quality of resistance sufficient.

7 On PETS, see for example: Goold (2009); ICO (2006) http://www.ico.gov.uk/upload/documents/pdb_report_html/privacy_by_design_report_v2.pdf;

8 On Privacy by Design, see: https://www.privacyinternational.org/category/free-tags/privacy-design; http://www.microsoft.com/privacy/bydesign.aspx; http://privacybydesign.ca/;

9 See for example: http://uk.reuters.com/article/2013/10/21/uk-eu-data-idUKBRE99K0LF20131021

10 This has some parallels with numbers as interface, see Holtrop this issue.

11 See for example: http://www.howtogeek.com/197436/what-happens-to-data-when-it-gets-deleted-from-your-recycle-bin/

12 However, arguments are on-going regarding who has responsibility to remove data. Is a search engine, for example, a controller of data (responsible) or a host for data (not responsible)? See: http://www.independent.co.uk/news/world/europe/eu-court-rules-in-googles-favour-right-to-be-forgotten-vetoed-8672512.html

13 Although this is an issue of on-going debate among privacy scholars: if an organisation has a back-up system that has stored data about you and then deleted the publicly available store of that data, to whom does this matter, is it a sufficient form of deletion, should expunging also incorporate back-up stores? For more on this, see: http://www.theguardian.com/technology/2013/apr/04/right-erasure-protects-freedom-forget-past Included within these popular discussions of expunging are guides on how to delete oneself which frequently allude to the difficulties involved: http://www.theguardian.com/technology/2013/apr/04/delete-your-digital-life-advice

14 Although zero has a longer history outside Europe, being recorded in a Bakhshali manuscript in the 3rd or 4th century AD: http://www.bbc.co.uk/news/uk-england-oxfordshire-41265057

15 This used a computing technique termed Kalman filter state vectors

16 Human operatives in the surveillance system only played a part at this point, some way down the chain of associations through which a decision might be made.

17 For the most part it was envisaged that the event detection algorithm would be limited through the deletion algorithm. Event detection would thus be prevented from running wild with data by continual deletion of that data.

18 For more on the importance of inverting the conventional metaphor of a product launch from sending an object into the world to building a world into an object, see Simakova and Neyland (2008).

19 On the shift of apparently mundane and mute figures into economic actors, see Cochoy (2009).

20 See also: Callon, Meadel and Rabeharisoa (2002) and Sjögren and Helgesson (2007)

Calculating Therapeutic Compliance: An Ethnographic Account of Numerical Inference and Interference in Mobile Health Care

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Abstract

This article discusses calculation practices in the development of a monitoring device, aimed at improving therapeutic compliance of children and teenagers suffering from a deformation of the spine. In managing the complexities of physical parameters, therapeutic measures, and interventions in everyday life, numbers are central participants in inferring from and interfering with bodies and behaviours. Numbers constitute the input and output of such monitoring systems, translating, circulating, and visualizing physical conditions and therapeutic effects, as well as suggesting action. This generative process of capturing and interpreting data has at the core algorithms, which process data and provide seemingly unambiguous numerical outcomes, based on mathematical and technological means of processing information. Attending to the incremental process of "learning algorithms" as a central feature of the system's development allows me to describe the robustness of certain modes of inference. Over and above using a specific case as an example for computer-based numerical inference and interference, this article attempts to probe and complement two theoretical approaches to the numerical management of complexity: Helen Verran's (e.g., 2001, 2010, 2013) focus on numbers' performative properties and the potential tensions arising from divergent numerical orderings, and Paul Kockelman's (e.g., 2013a, 2013b,) sieving of inferential and indexical chains along the generation of meaning and ontological transformativities.

Keywords: monitoring systems, numerical inference, ontic tensions, ontological transformativities, algorithmic processing, (non-)compliance

Introduction

Therapeutic monitoring systems are an increasingly common way of capturing, translating and visualizing physical parameters and the effects of therapeutic efforts on patients. One of many e-Health-technologies, such monitoring systems usually comprise of a sensor system and some form of communication interface to provide patients with feedback, prompting them to evaluate and potentially change their behaviour. In managing the complexities of physical

parameters, therapeutic measures, and interventions in everyday life, numbers are central participants in inferring from and interfering with bodies and behaviours. Numbers comprise the input and output of these monitoring systems, translating, circulating, and visualizing physical conditions and therapeutic effects, as well as suggesting action. It is this participation in inference and interference, which makes these numbers particularly interesting. In my article I attend to the management of therapeutic complexities through numbers in one exemplary case. Having worked with engineers and doctors and their numbering practices in developing a therapeutic monitoring system to improve compliance, as well as with patients (in this case children and teenagers), and the mundane calculation practices which make up part of their therapeutic effort, I was interested in the way the monitoring system calculations would relate to and possibly transform the embodied calculation of patients. What happens if digital processing becomes the central basis for the therapeutic management of complexities?

In the case at hand, the aim of the therapeutic monitoring system is to improve patients' therapeutic compliance by giving them precise feedback on their therapeutic performance. The feedback focuses on the actual time patients are pursuing therapy, in this case, the time during which children and teenagers wear their braces to correct for scoliosis, a deformation of the spine. As the daily duration of time for which the brace is worn is considered to have a central impact on therapeutic outcome, complying with the recommended duration (usually between 16 to 23 hours a day for at least two years) is regarded as crucial. At the same time, this therapeutic prescription proves to be an enormous challenge for these young patients as the brace itself disables them in various ways: the brace is of a rigid plastic causing pain in some cases, making the teenage wearers sweat especially during the summer, limiting their mobility and activity, while some see it as an aesthetic imposition. To prevent non-compliant behaviour, the monitoring system would capture the daily number of hours the brace was worn and would provide real-time feedback of the current number of hours to the patient via a smartphone app. Feedback in the form of an objective number is thought to potentially increase motivation and compliance to the advised hours. I am writing in the subjunctive as this article is not about the routine use of such a system. It is about the development of the therapeutic monitoring system and how numbers are generated by and generate assumptions about therapeutic compliance. Algorithms are at the core of this generative process of capturing and interpreting data, constituting a common basis for managing the complexities created by vast amounts of data and providing the basis for interference in people's lives. They process data and provide seemingly unambiguous numerical outcomes, based on mathematical and technological means of processing information. Attending to the incremental process of "learning algorithms" as a central part of the system's development allows me to describe the robustness of certain modes of inference. While the system in question is specific in many ways, several aspects of the development process and the device point towards more general discussions of monitoring systems in therapeutic contexts.

Over and above using the specific case as an example for computer-based numerical inference and interference, this article attempts to probe and complement two theoretical approaches to the numerical management of complexity. Focusing on the performative properties of numbers, Helen Verran's (e.g., 2001, 2010, 2013) work invites us to attend carefully to numbers in their ability to generate multiple relations and generalizations. Offering an entire toolbox for the investigation of the performative properties of numbers, Verran (2013) allows us to look at numbers as being generated in and at the same time being generative of collective action and order. This dissecting of numbers and their performative properties is the means to recognizing the "ontic and ontological tensions" in numbering practices and might bring us to recognize and engage with contesting political ontologies (Verran, 2014; for an alternative analysis of Verran's notions of ontic and ontology see Lippert, 2018). This interest in the tensions between different "enumerated entities" (Verran, 2010) leads us to focus on the perpetually 'becoming' nature of numbers and their capacity to change and flip from one generalizing mode to another, one semiotic manifestation to another.

Alongside the thrust of this special issue, numbers appear to be rather unstable entities. Yet my research on the development of the monitoring system and especially the mathematical and technological processing of data into an automated system made me aware of the robustness and durability of certain numbers. Central to this is the equipment of these automated numbers with a durable inferential profile that is the basis for interference. Understanding the configuration of inferential profiles is crucial for any intervention in the politics of algorithmic numbering. My focus on the robustness of certain numbers does not principally question the various dynamics of numbers' instabilities, as demonstrated by other papers in this special issue. Rather, there are several overlaps: for example with Neyland's (2018) paper on the development of a surveillance system and the attempt to automate deletion of unnecessary data by algorithms. His case study is a crucial reminder of the failures of such development processes and the undoing of calculation and qualculation (Neyland, 2018). Still, even though such projects fail or develop in other ways than planned, "successful", meaning solid working algorithmic processing is not an exception, on the contrary. To further delve into the creation of robust algorithmic processing and inferring, I propose a complement to Verran's performative properties. To do so, I draw from the work of anthropologist Paul Kockelman (2017) who is not explicitly concerned with numbers but with inferential processes especially in computer-based generation of meaning. Drawing from semiotics (as does Verran), among many other theoretical sources, Kockelman (2017: 128) invites us to attend to the "tangled, indexical and inferential chains, mediated by machines and algorithms as much as by humans". Processing information inevitably enchains "ontological transformativities" (Kockelman, 2013, 2017). Taking up his focus on interpretation or inference, I will discuss how the numbers produced by the monitoring system work as 'inferential devices': how they interpret and transform assumptions and action while being generated by ontological assumptions.

In my article I will employ both analytical offerings to discuss my material and will thereby hopefully offer a productive permutation of their ideas through my case study. Rather than comparing the two, my aim is to produce a recombinant, a combination of Verran's performative properties of numbers and Kockelman's inferential profiles.

Figuring out numbers in STS as/in relations of relations

Numbers' remarkable capacity to represent truth and objectivity (Porter, 1995; Hacking, 1990) has been scrutinized and amplified in the last years by various investigations in Science and Technology Studies, attending to the various work numbers do in different professional and mundane domains: from counting in classrooms (Verran, 2001) and supermarkets (Lave, 1988; Cochoy, 2008), to calculation practices and devices in economics (Callon and Muniesa, 2005) and financial markets (Zaloom, 2003), to governing practices in environmental politics (Asdal, 2008) and policy making (Ballestero, 2015) to epidemiological modelling based on enumerated entities (Bauer, 2008; Mackenzie, 2014), to mention some central fields of study. These studies have a particular interest in the ambiguity and performativity of numbers: how numbers are produced, how they circulate, legitimize authority, and constitute the realities they claim to represent. Rather than presenting numbers as belonging to one form of practice and contrasting it with another, those studies also highlight how numbers, as highly mobile devices, not only travel across divergent fields of action and styles of reasoning, but are also productive in creating new relations across different fields.

Yet the focus on numbers' capacity to circulate, to relate, to merge diverse systems and practices, also bears the risk of diffusing what we actually mean when we talk about numbering practices. As Ballestero emphasises, a calculation grammar, the arrangement of "people, technical instruments, and semiotic signs", is not only highly dependent on the concrete technical properties of its infrastructures but also on the "mathematical implications" it invokes (Ballestero, 2015: 266-267). What I summed up as studies on numbering practices appear to be rather diverse in the concrete procedures they invoke: quantifying, accounting, calculating, equating, valuing. Are these similar

practices simply because they all invoke numbers? To what degree do we need to differentiate between the concrete procedures and mathematical inferences invoked by 'numbering'?

By taking up this question I heed the plea made by Helen Verran who has emphasised the need to differentiate the diverse work numbers do. Verran has written extensively on numbers as "lively semiotic-material actants" (Verran, 2012: 66) in various fields and has defined them in her approach as "materialized relations" (Verran, 2010: 171). In her book *Science and an African Logic*, which generated years of focusing on numbers, Verran (2001) attends to numbering practices in Nigerian classrooms and the educational efforts to teach Yoruba speaking and English speaking children how to calculate in a scientifically sound, Western way. Disconcerted both by her research and by the relativist stance towards seemingly disparate numbering logics in her first draft, she variegates her own argument on numbers, developing an (re) account of numbers as multiple relations. Drawing from Marilyn Strathern's discussion of "the Relation" in kinship studies, Verran shows how numbers *have* relations and *are* relations, they are generated in and generative of collective action and order (Verran, 2001: 100-101). Consequently, numbers are addressed "as particulars, in time and place, *in situ* we might say – materialized; realized in specific practical ways" (Verran, 2010: 172). In this way, numbers are considered to be participants in collective actions where their performative properties variegate according to the microworlds in which they are embedded and embodied, the imaginaries they evoke and are evoked by, and the specific orderings they are engaged with.

Over the years Verran (2013: 28) has elaborated and refined the "epistemo-cultural properties of numbers" and their performative effects. Two of those properties proved to be especially relevant for my analysis: the semiotic manifestation of numbers (functioning as icons, indexes, or symbols) and the modes of generalizations they perform (whole-part or one-many generalizations). For example, the differentiation of numbers as icons, symbols, and indexes highlights which specific linkage between sign (e.g. number of hours the brace was worn;), object (e.g. the child wearing the brace), and the interpretant[1] (e.g. the correlation between hours and (non-)compliance) can be made. Are numbers in the therapeutic monitoring system working as icons, co-constituting (non-) compliance as a new whole? Or does calculating hours remain in the indexical zone continually referring to the embodied and situated practices of patients and doctors?

As I will demonstrate by juxtaposing the constitution of hours worn as duration (in the monitoring system) and time rhythm (in patients' mundane calculations), a focus on the various modes of performativity of numbers allows for a nuanced analysis of what is at stake in numbering practices. In Verran's work numbers' manifestations are rarely stable, but rather, they have the capacity to shift from one manifestation to the other, "flipping imperceptibly from their one-many manifestation to their whole-parts form of working, shifting between signing as symbols and signing as icons" (Verran, 2010: 177). Because of the limitation of my ethnographic research to the making of the system and the not-yet routine use of the system at this point of time, I am not able to venture into the potential "imperceptible flipping" of numbers' manifestations in therapeutic routines using the system. What I try to do here is slightly different. I wonder about the details of changing the performative properties of numbers from one relation to the other, from one semiotic manifestation to the other in the incremental machine learning process of the system, and ultimately about how they become durable. Elaborating on this specific case of machine learning, I attempt to open up the black box of algorithmic processing and similar to Adrian Mackenzie's (2017) work *Machine Learners*, though less comprehensive and archaeological, analyze algorithmic processing as a specific form of knowledge production and meaning making. How do local relations feed into generalizations and how do machines learn to make one-many generalizations? And how do these generalizations manifest as durable and opaque in this process? I argue that the potential force of algorithmic processing is the way in which numbers become durable, equipped with seemingly unequivocal inferential profiles. Inserting inferential profiles into Verran's toolbox for analysing enumerated entities to understand their relative

obduracy is the central recombinant I offer in this text by engaging with the work of anthropologist Paul Kockelman.[2]

Kockelman draws from a variety of theoretical sources, all centring around the idea of 'relations between relations', to systematize various processes of selection and significance as an on-going process of transformation (Kockelman, 2011, 2013a, 2013b). With his background in linguistic anthropology and his comprehensive systemization of a whole range of phenomena on various scales[3], he offers an at-times irritating mixture of stringent formalization and constant movement and shifting. There is no starting point, only continuous transformation; and yet he attempts to figure out the recurrent pattern in this complex "multiverse" of relations of relations. While he insists on the potential to use this analysis of patterns across various scales (Kockelman, 2011), much of his work is focussed on the very minutiae of information processing: the gesture, the utterance, the spam mail, the ticking of a clock (Kockelman, 2011, 2013a, 2013b; Kockelman and Bernstein, 2012), and therefore proved to be especially productive for attending to the details of computer-based inference and interference.

Like Verran, Kockelman draws on Peirce's (1974) theory of signs to set out his conceptual framework. In his conceptualizations he offers some helpful analytical categories and their linkages to elaborate on types of inference: the index, the kind, the individual, the interpreting agent, the ontology. Using the workings of spam filters as an example, Kockelman (2013a: 45-49) elaborates five forms of equations that form the basis for algorithmic processes (and assumption making more generally) and produce distinctive kinds of "ontological transformativity". With the notion of ontological transformativity Kockelman (2013a: 33) wants to foreground "the way ontologies are both embodied in and transformed by such algorithms". How are assumptions of the world, of an individual and accordingly indices incorporated into algorithms? And how does algorithmic processing loop back into ways of being and meaning making? Even though Kockelman is not explicitly dealing with numbers, his systematic analysis of relations of index, kind, individual, and agent and the transformation of ontologies complements the analysis of the workings of numbers in the concrete calculation practices I address. To discuss the 'inferential profiles' (Kockelman, 2013b, 2017) involved in the working of spam filters, Kockelman concentrates on the three modes of inference: inductive, deductive and abductive modes of inference. My central question concerns how and when numbers produced in such equations shift from one mode into another and become increasingly robust and durable. Kockelman's systematic semiotic vocabulary is productive in tracing the workings of mathematical and technological information processing through algorithms as continuous "inferential and indexical chains" (Kockelman, 2017: 128) which have the unique capacity to appear free of context given their technicality and high level of abstraction.[4]

While Verran and Kockelman are both interested in the way objects such as numbers or signs more generally come into being, gain and generate meaning, they engage different analytical devices to work through complexity management: Verran's (e.g., 2001, 2013) analytical device is a focus on the disconcertment arising from an encounter between different modes of numerical orderings. Juxtaposing the various performative properties of numbers, she emphasises the "ontic and ontological tensions" in these encounters, enabling the analyst to scrutinize the ontological politics at stake. Kockelman's (e.g., 2013a) conceptual device, on the other hand, is that of sieving endless connections and gradual shifts or, as I would call it, the incremental processing of ontologies and interpretations, altering both. Both of these approaches were productive for me long before this article, as they enabled me to look at different things or rather to look at things differently. My aim is not to symmetrically compare but rather to recombine their analytical approaches to generate an analytical device which captures what is at stake in the algorithmic processing and calculating of therapeutic compliance. This implies more than simply adding another concept, but rather invokes a recombination of the emphasis on *ontological multiplicity* and the arising frictions and *ontological transformativities* – the gradual transformation of ontological assumptions, espe-

cially in automated inference processes.[5] Part of this recombination will entail the integration of Kockelman's inferential profiles into the set of performative properties of numbers as proposed by Verran. I thereby propose to attend carefully to numbers' capacity to produce relatively stable assumptions about the world.

Yet my attempt to use the case study to effect engagement between the two by mapping Verran's conceptual framings of numbers and their 'epistemo-cultural properties' onto Kockelman's sieving process of 'ontological transformativities' created a strange effect of a gestalt-switch. This was productive for my analytical process, but rather difficult to capture in a linear text. In this article, I engage first with Verran's (2014) 'ontic tensions' to emphasize what is at stake in the development of the therapeutic monitoring system and the production of 'objective' numbers through the device. This allowed me to pause and scrutinize the performative properties of the device at the end of the development process by juxtaposing it with the mundane calculation practices of the young patients in their therapeutic routines. Subsequently, I will attend to algorithmic inference as incremental calculation. Here I retrace the development process and follow Kockelman's (2017) invitation to move along the chain of transformations to show how the generalizing mode of the numbers at hand is constituted through a cumulative process comprising sensors, a spreadsheet, human reasoning and tinkering, source code, among others. This retracing enables me to discuss how the coming into being of one-many relations occurs and how ontological politics are put into practice. The conclusion details the effects of this gestalt-switch. Before I proceed, I will provide more insights into my research and my case study.

Calculating Compliance: Case and Method

My insistence on the "gestalt-switch" is also a result of my research commitment. The aim of my ethnographic research was to accompany the technological developments of a large research cluster[6], including the monitoring system, in two ways: serving as a so-called ELSI (ethical, legal, social implications of technology development) project, the task was to address potential blind spots in the design and development of the technologies and introduce a broader critical reflection of the potential effects of such technologies. At the same time my aim was to provide ethnographic insights into potential users' expectations and experiences and to feed those findings back into the development process. One of the technologies developed in the research cluster was the monitoring system I focus on in this article.

This so-called "multi-sensor monitoring system" addresses the potential non-compliance of children and teenagers in scoliosis therapy. The aim of the system is to provide patients with feedback on their therapeutic performance via a smartphone application, assuming it will enhance their therapeutic compliance. In therapy and in the concept of the monitoring system compliance is defined by the adherence to the advised number of hours the brace is to be worn. Brace therapy is a common treatment for milder variants of scoliosis, which is a three-dimensional deformation of the spine, usually developing in the early teens and most responsive to corrective therapy during the growth phase. Hence, children and teenagers are the main patient group. Depending on the degree of spine deformity and the point in treatment, children are advised to wear the brace for 16 to 23 hours everyday for several years, whereby the rigid plastic "presses" children into the upright position. To no surprise, scoliosis therapy is demanding for children and teenagers in various ways, and adhering to therapeutic advice cannot be considered self-evident. Yet clinical studies and orthopaedic guidelines suggest a direct correlation between the number of hours it is worn, therapeutic outcome and potential long-term impairment.

To increase young patients' compliance to the advised number of hours a research team involving engineers, psychologists, orthopaedics, computer scientists, and usability designers developed the so-called multi-sensor monitoring system. The system comprises two main parts: a sensor system built into the brace to measure certain bodily values (temperature, moisture, acceleration, pressure) for the calculation of the hours the brace is actually worn; the outcome of this measurement is then provided to the patients

via a smartphone application. In more or less real time monitoring, children and teenagers are provided with a visualization of the actual hours and are expected to adjust their wearing performance accordingly. While the developers of the system acknowledge various factors leading to non-compliance, the main risk factor is considered to be the incapability and lack of motivation on the part of young patients to realistically estimate their hours through the day. Providing them with an "objective number" is considered to increase their motivation to comply. Additionally, the app offers information on scoliosis therapy, is equipped with an exercise programme, and a pin board with user stories as well as tips for the daily use of the brace.

My commitment to a critical dis/engagement with the development project shaped my argument in various ways. Sharing the task of providing patients with better solutions and assistance in handling the impositions of brace therapy, I was cautious of the powerful effects of monitoring users' therapeutic performance with respect to their (non-)compliance. To critically engage with these potential effects I carefully attended to the different calculation practices in the project and their potential implications. Through participant observation in therapeutic settings, such as a children's orthopaedic hospital specializing in scoliosis, and through open-ended interviews with 44 young patients (some at home, some in an orthopaedic hospital, some at the brace manufacturer), I learned about the young patients' everyday therapeutic routines and their struggles to adhere to the therapeutic advice. At the same time I regularly attended working meetings of the development team, conducted a series of interviews with the engineers, contributed to an observational study of the monitoring system at the end of the project and provided feedback on my preliminary findings to the development team during the process. So all along the research process I was constantly juxtaposing the therapeutic routines of the patients and the development process of the monitoring system. Numbers were crucial in both: in patients' day-by-day efforts to attain the expected number of hours; and in the project team's efforts to produce objective numbers by measurement and algorithmic processing of the sensor data.

This constant juxtaposing had two effects: first, it made me aware of the different generalizations of wearing time: In the development project, wearing time referred to the overall duration of hours the brace was worn within a 24 hour window; it was a total; in patients' therapeutic practices, wearing time mainly referred to the concrete time in the course of a day, a passage of time. Yet the second effect was somehow the opposite: Attending to the struggles of patients in their daily lives and engineers as they went about their daily work made me aware of the similar messy grounding of algorithmic and embodied calculations. Both "need to wrestle with the (…) buzzing real", as Verran (2012: 120) has phrased it. Just as patients have to learn to calculate "correctly", the monitoring system – and its programmers, engineers, and algorithms – had to gradually learn to translate and perform numbers in a specific way. Both are ways of managing complexity. Yet with regard to the monitoring system, the learning had to come to a closure by the end of the development project. The calculation of wearing time through the system had become valid and robust. Before I elaborate on the development process, I first attend to the system as it was at the end and juxtapose it with a young patient's mundane calculation practices.

Juxtaposing hours worn as duration and time

Let me start with the monitoring system as it was working at the end (as a prototype). The central question concerning the system was how many hours per day the teenager wore the brace and whether this conformed to the therapeutic prescription. So we have a number somewhere between 0 and 24. I choose '16' as an example, which is a fairly good wearing performance, but not entirely perfect. The hours worn are visualized on the screen of the teenager's smartphone in the form of 16 cute little kittens (see Figure 1). For each additional hour the brace was worn according to the sensor system, one more kitten appeared during the day. In the weekly overview the actual hours it was worn each day are presented in the

form of a bar chart where a green line indicates the advised hours (see Figure 2). The number of the advised hours headlines the chart and the actual hours, e.g. 16, are displayed above the bar for each day. But how does the system calculate the numbers of kittens and bars? Generally, the kittens (and bars) are the outcome of a classification system: no kitten stands for "not worn" and a present kitten for "worn". It is a simple binary system – a 'yes' or a 'no'. The system classifies the captured data into yeses (1) and noes (0) and adds up all the "yeses" for a total sum, e.g. 16. Sensors do not capture data continuously, but every five minutes.[7] So for example, the sensor system might capture data at 9:55 a.m. and then classify whether the user was wearing the brace or not at this point in time according to the underlying algorithm and presumes that this classification is correct over the five minutes until the next measurement. Once there are 12 points of measurement classified as "yes, worn", another kitten appears on the display (12x1x5=60). This might be at 10:50 a.m. or much later. There is no quarter or half kitten. The system first expands point-measurements to 5-minute intervals and then adds those times (duration) up for an overall duration within 24 hours. In my conversations with the engineer who was developing the measurement system and the algorithms for the classification, she made me aware of an important distinction: Even though in the project we generally spoke about "wearing time" monitored by the system, it is actually "wearing duration". It is not the actual time of day, e.g. 9:55 a.m., that is important but the summation of discrete time units to quantify the duration the brace was worn. Duration in the system's construction therefore does not refer to an interval between two points in time, which might correspond to a more intuitive understanding of duration, but a cumulative length, consisting of discrete units. Before I further delve into this difference between time worn and duration worn, let me pause and explicate the 'performative properties' of the numbers produced in this calculation practice. As stated above, Verran (2013: 28) has elaborated and refined the "epistemo-cultural properties of numbers": their modes of generalizations, their ontological manifestation as well their semiotic manifestation

Figure 1: Screenshot of current hours worn

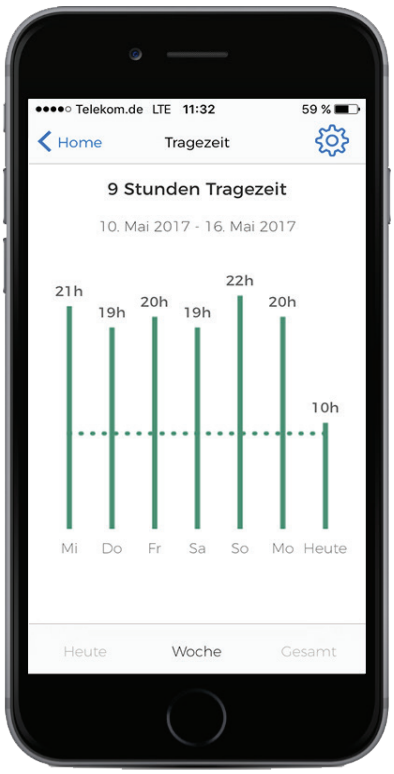

Figure 2: Screenshot of summary of weekly hours worn

Both figures were provided by the project partner at Berlin's University of Arts

and the temporalities by which these modes are modified. Two properties proved to be especially helpful in my analysis of the numbering practices in the case at hand: the semiotic manifestation of numbers and their mode of generalizing unity-multiplicity relations.

Drawing from Peirce's theory of signs (yet twisting it in her own way, see for example Verran, 2010: 172), Verran invites ethnographers to attend to the different workings of signs as symbols, icons or indexes, and the specific co-constitution of signs, collective action, and the objects generated within these workings. While indexicality strongly implies the here and now and the existential co-constitution of object and referent, symbols and their objects perform a relation of supervenience, whereby "objects are accepted as affecting and effecting their signs but not vice-versa", as Verran (2010: 172) explains. Numbers represent objects, phenomena, 'reality'. Iconicity, the third semiotic mode of numbers, in contrast, highlights a collapse of any distinction between number and category and their capacity to generate order. Here sign and object are treated as one and alike (Verran, 2012: 116). This first distinction of numbers' performative properties allows me to analyse numbers' workings as different manifestations of the co-constitution of signs, the objects, and the collective actions in which they are embedded: literally pointing towards what is being counted (indexes), representing it (symbols) or constituting order (icon). These semiotic manifestations of numbers are intertwined with the way generalizations are performed through them. Starting with indexical numbers which "dwell in the mess of the real (…) generalizing can proceed simultaneously as whole-parts and one-many" (Verran, 2012: 120). Something is being (re)counted in the here and now, and from here generalizing can proceed in two ways. Performing one-many relations is a common generalization technique in many scientific practices and beyond; starting with discrete units, which are collected to a coherent cumulus of many; the resulting numeral (e.g. 16) abstracts and represents the plurality of many. Quite differently, whole-part generalizations refer to multiple emergent parts from a vague whole. While in the former, numerals are representations/symbols, in the latter they become iconic, constituting the world.[8]

Let me further discuss this in relation to the calculation made by the system described above. The calculation starts by capturing data every five minutes. The data, e.g. the temperature of the brace at this specific point in time, is processed by an algorithm for classification under yes (1) or no (0). In algorithmic processing, the existential relation between sign and its object (e.g. the temperature in the brace expressed as 36,9°) is transformed into the conventional binary system of 1 or 0. So while 1 still refers to the data of bodily parameters, its binary reworkings manifest it as symbolic. In the logic and processing mechanism of the monitoring system, calculation proceeds by adding discrete units to a total, first to a full hour and then to the overall duration the brace was worn during a day. In summing up discrete units of a defined measurement, the monitoring system and the produced number perform 'realistic', objective' representations where physical processes, e.g. temperature, are transformed into signs and visualized as numerals. As Verran (2010) has stated, in this semiotic manifestation as symbols, objects effect signs but not the other way around. This calculation appears to be a solid technical calculation process with clearly defined units and an unambiguous outcome. The reference point or frame is the 24 hour day, yet not as a course of time but duration as the cumulation of hours which are the result of sums of smaller time units classified as "yes, worn." It is a metric version of time, consisting of quantified units. In the generalization of a one-many relation, the number 16 manifests as a symbol. This is how many hours the teenager "really" wore the brace. Overall, this is the aim of the monitoring system: to provide children and teenagers with objective numbers to correct their often unrealistic calculation practices. In this sense, the 16 kittens are a truth claim, based on algorithmic processing of physical parameters, a seemingly neutral mathematical and technical procedure beyond subjective bias and human errors. In a combination of the connection between the medical correlation of numbers of hours worn to therapeutic outcome and the technical processing of physical parameters to an objective representation of ther-

apeutic effort, numbers come to demarcate therapeutic compliance in an unambiguous way. It is either yes or no, either 1 or 0, and further, based on the unambiguous measurement of the total duration per day compared to the advised hours, it results in another binary interpretation of either compliant or non-compliant. There is no room for alternative interpretations or excuses, (non-) compliance is a fact.

The monitoring system is designed as an intervention in the wearing routines of the patients.[9] To inquire into the potential implications of the system, part of my research attended to the actual wearing and calculation routines of the patients. As I will show in the following section, children and teenagers (mostly) agreed on the difficulty of calculating wearing hours correctly (and were enthusiastic about using such a system); yet most of them nevertheless felt competent to handle the calculation of wearing time "most of the time". Their calculation, however, differed from the time measurement of the monitoring system. To elaborate on this difference, the generalizations made and the relations numbers are/have in these practices, I will juxtapose the performativity of numbers in the monitoring system with the embodied calculations of the young patients. What is the potential 'ontic tension' which might arise with the implementation of the monitoring system in everyday therapeutic routines? How might it interfere in the patients' everyday calculation practices?

Calculation practices in the 'indexical zone'

At first glance what children and teenagers were interested in was also duration worn. Their primary concern was: "Did I wear it enough?" For most of them, the actual number of hours they wore the brace during the day turned out to be hard to grasp. When asked whether they thought they could realistically estimate their hours, a common answer the young patients gave was: "Sort of, yes" or "most of the time". Inquiring more into their everyday practices of wearing the brace, this "sort of" and "most of the time" proved to be quite a challenge: "You think you just took it off for a couple of minutes and then it turns out it was more than an hour," a teenager explained. Wearing the brace, time seems to run slower, it makes everything more difficult: "I thought I wore it for ages but then recounting the time with my mom, it turned out it was just for an hour." Also those who were convinced they "sort of" knew most of the time, admitted that sometimes they got the hours totally wrong. Overall, the counting and calculation of hours worn very much depended on the daily routines and the regularity of their daily activities. In a way, the focus on the question "is it enough?" points towards an understanding of wearing-time as gradual and relative to a value-schema and highlights the situated judgments of these young patients. Yet the judgment around 'enough' is always made vis-à-vis clearly defined (by doctors, parents, therapists) quantities, which serve as reference.

This struggle to grasp the hours worn and to count "correctly" became obvious when several teenagers finally had the opportunity to test the prototype of the monitoring system at the end of the development project. All of those who participated in the study embraced the idea of having real-time feedback of their hours through the monitoring system. Finally, they could "see" the wearing-time, was an often made comment. They could finally see what was otherwise complicated to perceive. And they enjoyed collecting kittens and found it a fun challenge to accumulate as many as possible. Yet there was also a quest for another form of visualizing their wearing hours. Interestingly, the test persons came up with a similar distinction of "wearing time" and "wearing duration" as the engineer I referred to above. In addition to the display of the overall duration within a 24 hour period, they wanted to "see" the actual times during which they wore the brace: e.g. from 8 a.m. to 4 p.m. As Aaron, a 17 year old teenager, explained, to understand at what point his counting "went wrong" he needed to have the actual time:

> The way it is designed now, I still don't know when I wore the brace and when I didn't. (...) If I had the exact times I could see, okay, every time I think I just took it off for a couple of minutes or so to do some exercises, but it was actually two hours, I would know when I got it wrong. If I had the exact time I would know the reasons.

What Aaron describes here emerged as a general theme in the interviews with children and teenagers. Recounting their wearing practices, children and teenagers did not offer a total number of hours per day, but related the wearing time with certain activities at concrete times. Typically school and sleep were central routines that they referred to. One teenage girl, for example, who had been advised to wear the brace for only 12 hours a day, preferred to wear it at night and not during school. "I need to put it on in the evening before we have dinner or I watch TV. Or else I don't reach the 12 hours, because I don't sleep 12 hours. But then in the morning I can take it off before I go to school." Others prefer to wear it at school and not at night. "I want to be well-rested for school, so I don't wear it at night. I never got used to sleeping in the brace, so I prefer wearing it in school. When I am sitting, it is rarely a problem."

In describing their daily routines, children and teenagers generally divided their daily rhythm into three blocks: sleep, school, and leisure time. This is a typically modern way of structuring time into labour time and leisure time. Most of them avoided wearing it during any leisure activities, when they "just wanted to chill", or were hanging out with friends. A consistent rhythm helped most of them to gain some sort of routine. But as their days differ from one day to the next, this kind of habituation is also a challenge. As Laura explained in detail:

> For example, when I am on the go the whole day and I know it will bother me, maybe while running to catch the bus or when I go shopping and will be walking around a lot, then I leave it at home and wear it at night instead. But when I know, okay I will be at school and have nothing else planned afterwards, then I wear it to school. And in the summer, when it is really hot, I sometimes do not wear it at all. But besides that, I wear it all the time. Yes, really, all the time.

What those children and teenagers indicate here is a strong link between hours worn, daily activities, and the requirements and conditions these activities bring with them. Moving a lot means you sweat (it is a rigid plastic brace); having to run is hard if you are limited in your mobility by the brace; participating in gym classes or other activities, means you have to find a place where you can lock the brace. Summer is different from winter. And so on. So while, interestingly, children and teenagers do refer to indexes similar to the data captured by the sensor – temperature, acceleration, moisture, pressure – they "process" these indexes in a different way. Their calculation practice is fundamentally embodied as it takes the moving body in the environment into account. While generalizing their hours they move back and forth from concrete contexts and activities to the whole day and the whole week. This reliance of children's and teenagers' calculation practices on concrete context and activities is inherently indexical. Certain weekdays, school schedules, seasons and their temperatures display a complex index for their calculation practices. While they attempt to arrange the wearing of their brace to add up to enough hours each day, the advised time is an ideal, which does not strictly order their day. Whereas the monitoring system sums up discrete time units to a daily number of hours worn and proceeds in a one-many ordering, children and teenagers related wearing-times to the course of a whole day. In Verran's (2013) words, they engaged in whole-parts relating. Their ordered/ordering microworlds are impacted to a large extent by the division of time along school and leisure time and co-constructed by a schooling system that operates on a five-day school week ontology. This became obvious through an interesting discrepancy between the way in which children and their parents calculated hours worn and the medical logic of calculating hours worn. Again and again, I came across the explanation that a lower number of hours worn on a weekday would be compensated on the weekend. Parents legitimized fewer hours on a school day with reference to higher wearing hours on the weekends. When I asked the orthopaedics on the team, they were rather surprised by this widespread misunderstanding and stated that this made absolutely no sense from a therapeutic point of view. Their medical bodies are not subject to the ontological distinction between workdays and weekends. Yet in the microworlds of patients and parents this made perfect sense, like catching up with homework on the weekend. The entirety of a day or

even the entirety of a week was the reference for generalizing wearing hours.

Most importantly, this whole-part generalizing allowed for a rethinking and re-evaluation of compliance in many ways. Take the story of Jenny as an example. In an interview she recounted the time she actually had a temperature sensor built into her brace, which recorded her wearing behaviour similar to the monitoring system of the project. While the monitoring system aims to feedback the hours worn in real-time, Jenny's doctor read out the "temperature chip" in the consultation room once a year.

> When we looked at it, I saw that there were actually a couple of days where the hours were extremely low, where I wore it very little or not at all. So I was like: Eh, what happened there? So I investigated a bit and as it turned out, yes, that was when I did a lot of exercise or it was somebody's birthday, so I kind of exercised as we probably went dancing. So at first I thought, oh shit, I didn't wear it enough and when I looked at what I actually did that day and why I didn't wear it, I wrote it down, so that I have an excuse.

While Jenny and others are committed to achieving the advised hours, these numbers became neither symbols nor icons. Simply accumulating kittens might be fun and it might tell them where they stand (numerically) at a certain point in time, but it does not relate back to their daily activities and the concrete contexts of their daily routines. While children and teenagers (and their parents) were engaged in whole-part generalizations, the numbers of hours worn did not quite yet become icons either. The number of hours worn and the category "compliance" were not treated as one and the same, as for example in medical logic. Rather, their calculation practices remained unstable and open to rethinking and redesigning – and therefore remained in the 'indexical zone'. The lack of kittens could actually be reinterpreted as an index of a birthday party. This allowed them to "make excuses": it situated (non-)compliance in everyday routines and their impositions and affordances. The "correct" number was in a sense not the advised duration worn but the number achieved in an adjustment of brace therapy with everyday routines in the course of a day as a lived sleep-school-leisure rhythm and the school week.

This juxtaposition of children's and teenagers' time reckoning[10] to the monitoring system's calculation of time units and one-many generalizing was in itself an analytical time twist: I took the monitoring system as it was (more or less) finalized at the end of the project, confronting it with the on-going therapeutic routines of the patients unfazed by any real-time monitoring. While this gave me the ability to problematize the potential conventionalization of certain calculation practices and the use of numbers as symbols to make truth claims, it presents the monitoring system as a somewhat context-free technological device. It is a device engaged in manifesting numbers as symbols and is an example of the reworking of mundane calculation practices and interventions into problematic behaviour based on computerized processing. However, looking back into the development process, the system's processing of numbers was for the most part at least as messy and indexical as the children's and teenagers' juggling of hours worn during a day or week. Even though it is a rather straightforward example of a combination of sensors, algorithmic processing, and a smartphone application, it took the project team and the engineer responsible for the measurement and development of the algorithms a lot of effort to produce durable and robust symbolic numbers.

Algorithmic inference as incremental calculation

The question I will pursue in the following pertains to how one-many relations become so robust that they gain the capacity to impose their reasoning on certain microworlds. More concretely: How did the monitoring system's generalizing of (non-) compliance become so robust that it could reconfigure what compliance was in the microworlds of young patients struggling to achieve compliance to advised hours? This is not an argument for a deterministic framing of the monitoring system. The routine implementation of the device is still a project of the future, and as I have shown, children and teenagers already have to incorporate various demands into their calculation practices

and were mostly able to create arrangements of therapeutic and other obligations that suited their specific needs. Yet, as the monitoring system is a device which is designed specifically to "correct" children's and teenagers' calculation practices, its appearance as robust, objective, along with its ability to provide immediate feedback in real-time has the potential to transform not only how compliance is experienced, but also how it is accounted for by doctors, parents and other parties, such as insurance companies. The aim of this research was to trace the configuration of this "robustness" which was usually framed by the project team as simply the (planned) outcome of technically and mathematically processing physical parameters. This robustness, I argue, is achieved in an incremental process: through a cumulative, shifting process and the gradual manipulation of data, the inferences made in these calculation practices shift from inductive to deductive.

The definite set of the system's indices and the classifications inferred from them take us to the core of what is at stake in algorithmic data-processing. Compared to other examples of algorithmic processing the system at hand might seem rather banal. The data sets are small, hardly Big Data; the algorithms implemented are very basic compared to the complexity of intelligent algorithms. Yet, by attending carefully to this developing process as an incremental process, I intend to show how algorithmic processing as an increasingly common component of one-many generalizations becomes effective in a specific way. As I show, this effectiveness is produced in a complex human and non-human intermingling of data, its clustering and reworking, and technological and mathematical procedures. At the end, these workings seem to become opaque, hardly understandable or questionable.

I came across this opaqueness when I was working with one of the engineers responsible for developing the data processing system. My overall aim, investigating along the development process, was to understand how the imaginaries of the project and the involved stakeholders, and the materialities of sensor, brace, and smartphone etc. would potentially reconfigure what compliance was (Suchman, 2007). I wanted to understand the architecture of the data processing system and found myself venturing into the world of algorithms and machine learning. I particularly remember my excitement in one of our conversations. The engineer had drawn (yet another) sketch of the different steps involved in data processing and machine learning to explain her work to me: producing data in the lab, developing features, training the algorithm with all but one data set, possibly adapting features, training the algorithm once again before testing it with the last data set, and finally evaluating the recognition rate of the algorithm. At some point she tapped on the drawing with her pen and said: "And this is where the direct link between data and decision [yes/1, worn vs. no/0, not worn] disappears. This is not comprehensible to our eyes and our human logic anymore. But with all those coefficients in our equation we can deal with the potential variance." Following this conversation, I spent a lot of time trying to trace and understand this moment where "the link disappears". I envisioned some magical moment of shifting where suddenly the algorithm took over. Eventually I had to accept I had fallen, as many others, for this mystical techno-fantasy of "the algorithm". As it turned out, there is no such magical moment. There are many small steps and there are some important transformations in the processing of data before those 16 kittens appear on the screen. No sudden flip but a continuous cumulative shifting process, where data, features, algorithms are manipulated and adjusted to finally generate the definite decision: yes - no. In striving to make sense of this incremental process of data processing and machine learning, Paul Kockelman's (2017, 2013a, 2013b) systematic focus on transformations of relation (of relations), his repertoire of concepts, and his specific interest in computerized interpretation processes helped me follow these transformations.

Like Verran, Kockelman draws on Peirce's theory of signs to set out his conceptual framework. In his elaboration of the workings of equations in the example of an algorithm for spam filters, he starts with the following semiotic categories and their linkages to elaborate on types of inference: the index, the kind, the individual, the interpretative agent, the ontology (Kockelman, 2013a). As Kockelman (2013a, 2013b) himself states, it is

less about the terms but how they are defined; so to reproduce his definitions: "the term index will be used to refer to any quality that is relatively perceivable to some agent" (in the case of the monitoring system, the increase in temperature, sweat, movement among others); "the term kind will be used to refer to any projected propensity to exhibit particular indices" (in the case of the monitoring system, the two kinds are simply 'worn' or 'not worn'); "the term agent will be used to refer to any entity that can perceive such an index and thereby project such a kind"(the engineer in the lab or at the end the monitoring system itself); "the term individual will be used to refer to any entity that can evince indices to an agent and thereby be a site to project kindedness" (the wearer of the brace); "the term ontology will be used to refer to an agent's assumptions as to the indices, kinds, and individuals that constitute a particular world" (the assumption of validity and objectivity of the monitoring system's processing of sensor data and the resulting inference of (non-)compliance) (Kockelman, 2013b: 40-42, 2013a: 151). Using the workings of spam filters as an example, Kockelman (2013a: 45-48) elaborates five forms of equations that are the basis for algorithmic processes (and assumption making more generally) and that produce distinctive kinds of 'ontological transformativity'. Ontological transformativity encompasses both how interpretations (of an agent, based on indices, referring to a kind) mediate ontologies (assumptions concerning an individual and/or kind) and how, vice versa, ontologies mediate interpretations.

To explain the different transformativities and modes of inference involved in the working of spam filters, Kockelman concentrates on the three modes of inference which he refers to as (relatively) deductive, inductive, and abductive.[11] I will again repeat his definition of these as he uses them in various texts: in the relatively *deductive* kind or inferential profile, "indices may change an agent's ontological assumptions regarding the kinds that constitute a particular individual"; in the relatively *inductive* kind or inferential profile, "indices may change an agent's ontological assumptions regarding the indices that constitute a particular kind"; and in the relatively *abductive* kind or inferential profile, "indices may change an agent's ontological assumptions regarding the indices, individuals, kinds, and agents that constitute a particular world" (Kockelman, 2013a: 46-47, 2013b: 151-152). I suggest Kockelman's systematic semiotic vocabulary is productive for dissecting the inner workings of mathematical equations such as algorithms, which have the unique capacity to appear free of context given their technicality and high level of abstraction.

Let me return to the development process of the monitoring system. As I described above, the sensors capture data, which serves as the basis for the classification "worn" or "not worn". With Kockelman's vocabulary we have the sensor-system (the interpretative agent) which produces robust inferences concerning kind (worn – not worn) based on a fixed set of indices: a certain temperature range, rate of acceleration, humidity in the brace. What the algorithm needs to predict is whether – according to the indices – the individual belongs to the kind "wore the brace" or "did not wear the brace". To be able to do so, the algorithm needs to be trained. Just as the children and teenagers have to learn calculating the hours they wore the brace correctly, the monitoring system had to be trained to make the "correct" inferences based on the data produced by the sensors.[12] The engineer started with four types of sensors, which captured acceleration (through one sensor outside the brace), pressure (through one inside), moisture (through a sensor inside and one on the outside of the brace), and temperature (again through one inside and one on the outside of the brace). In her lab she equipped test persons with a provisional measuring system to produce data. In the lab situation, there is an observable link between data (on her screen) and reality (the test person doing motion sequences with and without a brace). The engineer sees that the brace is worn and what kind of data wearing the brace produces, e.g. the rise in temperature once the brace is put on, the change in the temperature difference between the inside and the outside of the brace. For the engineer this is the rather boring part of collecting data. She eventually got used to my fascination with numbers, and we sat at her computer one day to stare at rows and rows and rows of numbers consisting of nine digits. The rows are the output of the laboratory measurements. For

each test person she has a folder with a number of spreadsheets, each spreadsheet sheet comprises the data of one sensor. For example, there are two spreadsheets for temperature. While the numbers in the spreadsheet table T1 (the temperature on the outside of the brace) only slightly change after the decimal point (e.g. from 24.6789012 to 24.8765432) the numbers in T2 (measured by the inner sensor) consistently increases (e.g. from 23.4567890 to 36.4637485). These rows of numbers were her starting point:

> I first collected data and then analysed whether the temperature differed significantly between 'worn' and 'not worn'. Then I took the respective average values [of all test persons]: average temperature of brace when worn and average temperature of brace when not worn. Then I calculated the mean of the two values, and divided the difference in two. That is my limit value. This is a method like any other method.

She draws a graph with an x and a y axis and draws a line representing the numbers, showing an increase in temperature. More than 32, it is worn, less than 32, it is not worn. This is the outcome of her observations in the lab: "So first you have a cloud of data. And then you make your first differentiation in the data. Which is based on simple logic. I made the decision simply according to our central question: is it being worn or is it not being worn. That's simple logic."

What she calls simple logic here is an inference starting with the kind or classification "worn"/"not worn" which she observes in her lab. From there she further elaborates which indices constitute that kind. Is 31,7°C an index of worn or not worn? Which is the limit value where a number could be an index of either worn or not worn? This "simple logic" can apply in real time or hindsight explorations. They do not project forward, but induce from what is or has been observed. Based on observation of the test person, brace, and data, the agent (the engineer) creates a range of indices, which potentially constitute the kind. To process the relatively small-scale data-based indices (e.g. 23.4567890 or 36.4637485) into groups, she uses "features" which help her to reduce the multitude of indices.

What the engineer described as a method based on "simple logic" is called "feature engineering" in machine learning. Even though not formally part of machine learning, but rather a prerequisite, feature engineering is often described as the most time consuming and essential part of machine learning (Domingos, 2012; Guyon et al., 2008). As features are domain specific it is difficult to describe them in an abstract way. Basically, the task of features is to "prepare" the data for algorithmic processing. Or to put it in another way, to establish some basic differentiations, which potentially cluster the data into certain groups (of indices). In the project the engineer worked with three relevant types of features: limit values, standard deviations, and one termed signal magnitude area. The latter was relevant for processing data pertaining to pressure and acceleration in order to distinguish between static and dynamic activities. Another feature would be the limit value of the temperature difference between the inside and the outside. For moisture, it is easy insofar as one can assume there is zero humidity at the beginning, so any change points to "worn" (the sensors have in-built heaters, so once the brace is taken off any moisture vanishes quickly). At the end of the feature engineering process there were altogether 14 features. Features are in a sense small-scale generalisers, enabling one to abstract from the multitude of data a cluster of indices. Yet, these features alone do not accumulate units. Rather, they describe what could be part of the unit. And they remain attached to the data and "their" objects, e.g. temperature. But an important initial disentanglement is produced in the process of feature engineering. While the engineer is able to relate the features and the processed data back to the timeline of the spreadsheets and the here-and-now of the lab situation, the features themselves have no direct reference to the time line anymore. The transformation from calculating along a course of time to the cumulation of time as duration begins. But it is not an abrupt disentanglement, for during the training process, data, features, and timeline are constantly connected and reconnected via the engineer.

In this first step of developing the data processing system we can see an inductive mode of inference: observing a phenomenon, defining

features of the index. The starting point for inferring in the inductive mode is the observation of a case, where the relation between kind (worn/not worn) and individual is clear. What is potentially transformed is the relation between kind and indices. Once the engineer has a fair number of features, she trains the algorithm with a data set. The whole process is an iterative development, as the engineer explains. When she has a data set, she uses all but one sample to train the algorithm, or rather, various types of algorithms. She does not work with algorithms as mathematical equations, but with "ready-made" software packages in the programming languages of different types of algorithms, provided in an open source library of machine learning, which she can implement, combine, and modify. In a sense she draws from the accumulation of machine learning methods, which themselves are the result of incremental learning in computational science. As Adrian Mackenzie (2017: 22) points out, machine learning itself should be understood as "an accumulation rather than a radical transformation", taking shape "against a background of more than a century of work in mathematics, statistics, computer sciences as well as disparate scientific fields ranging from anthropology to zoology". The part of the development process I depict in this text is but a small sequence in a much longer inferential and indexical chain.

Based on her experience and some literature review, the engineer chooses a few relevant types of algorithms, such as the "*k* nearest neighbour", the "support vector machine" or the classic "decision tree" which seem relevant for the questions she intends to answer. After a phase of training the algorithm, she uses the last sample of data to see if the algorithm comes up with the right solution. This form of machine learning is called "supervised learning algorithm" in software engineering (cf. Mackenzie, 2017: 84-85). Based on the quality of the outcome she goes back to the features and "fiddles around" with them, as she calls it, then generates another data set and so on. Are the features chosen accurate enough, valid enough, the right ones so that the algorithm produces the right assumptions for the kind? Iteratively moving from features/indexes to assumptions/inferences, the validity of the system is ensured, as Kockelman (2017: 128) writes, "in long, tangled, indexical and inferential chains, mediated by machines and algorithms as much as by humans". The central goal is to find the combination of features – algorithm relation (or possibly a combination of several of them), which gets the highest recognition rate of the symbol worn and not-worn.

Learning needs to be completed before the algorithm leaves the lab. The iterative process needs to come to a closure. Kockelman (2017: 25) describes this as a prototypical form of enclosure in computer science (and beyond), involving "processes of objectification, formatting, stabilization, and containment (and sometimes even ways of escape)". In the case at hand, a final selection was made. At the end, one algorithm operating with one feature turned out to be valid enough to produce a recognition rate of 98%. A combination of two of this one set with another set of one algorithm with one feature reached 99%. From this point on, the system was working with a deductive inferential profile, based on the assumptions it was trained to make. The inference is finally disentangled from the observation of "worn" and "not worn" in the lab and the concrete time the actions took place. As the engineer summarizes:

> As long as we develop the algorithm we have a clear mapping with reality and we see what the algorithm spits out. Once we are done with the developing process and can't see the patients anymore, we simply do not know what really happened. We only have our assumptions.

The sensor-system and the algorithms filter out noise for signs in order to make inferences about the kind present. Much of the engineer's work is to train the algorithms with data, features, and then to compare the outcome to the phenomenon observed "in reality". Along the way, the algorithms learn to make increasingly valid assumptions; if they get something wrong, the features are reworked or another algorithm is chosen. The aim is to implement a combination of algorithm(s) and feature(s) that fits the data and the kind in question. While there is much debate on the opaqueness of algorithms and their relative autonomy in decision-making, I like to

emphasise that this autonomy is fundamentally distributed: the features and data are assumptions that are very much based in the materiality of the sensor system as well as in the logic (and beliefs and desires) of its developers. Nevertheless, at the point of closure, the inferential profile has shifted from inductive to deductive. While for most of the developing process, the distinction between "reality" and "algorithmic reality" is crucial, once the learning process ends, they are conflated. Or, because they merge, learning stops. The numbers produced with the monitoring system have moved from the indexical zone to become conventions, or symbols as Verran calls them, now generating one-many relations, bringing forth kittens on the screen of a teenager's smartphone. One could claim that this is actually the moment where the algorithm "takes over". But as I have hopefully made clear, this gradual shifting towards deductive inference is distributed in a specific way and is the (preliminary) result of a long "inferential and indexical chain" (Kockelman, 2017: 128). This chain started long before the moment in the lab when I switched on the ethnographic light. The question remains as to how patients will interpret the monitoring system and the objective numbers and alter their assumptions on compliance.

Conclusion

This article addressed the sensor monitoring system and young patients' calculation practices, sieving through the empirical and building an argument using concepts developed by Helen Verran (e.g., 2010, 2013) and Paul Kockelman (e.g., 2013a, 2017) . Switching between Verran's careful attention to 'ontic / ontological tensions' to Kockelman's sieve of 'ontological transformativities', I was moving from the system as it was developed by the end to the microworlds of the patients and back to a retrospective dismantling of the step-by-step process of the system's learning. Throughout the analytical and especially the writing process, I had to actively construe those sieves which did not really fit at the out-set. Kockelman's sieve is fine-grained yet isn't able to capture the tension generated by the different "versions" of numbers' workings as one-many relations and whole-part relations. Or is there something like a double-sieve? At the same time his sieves are especially well-attuned to the dissecting of computer-based techniques of making interpretations. Moving along the incremental process of developing a robust, valid, seemingly autonomous calculation device enabled me to focus on the reworkings of numbers in a constant recombination of data, features, and algorithms. While much debate focuses on the deductive, reductionist and at the same time seemingly opaque workings of algorithmic processing, I mainly focussed on the moment before the deductive mode of inference was implemented. The management of complexity is performed in disentangling data from its empirical grounding to slowly transform numbers that perform indexicality into numbers that function as symbols. Becoming a deductive device is a process involving sensors and captured data (in the lab), its iterative manipulation based on "human logic", training and testing algorithms to make valid inferences. To understand what is at stake in algorithmic processing, this is the process at which we need to take a closer look. What are the assumptions that become embodied in the algorithmic inference and how might this alter ontological assumptions about compliance? I proposed introducing another performative property to Verran's repertoire: numbers' inferential profile and their capacity to make durable and unequivocal assumptions about the world and to interfere in the world.

According to the logic of the technology developers, the production of correct calculations can only be achieved through disentangling complexity and reducing potential nuisances on the way; juxtaposing the calculation practices of the system with the complexity management of the young patients brought into focus a very different form of complexity management. Recall the story of Jenny who was checking the outcome of the temperature sensor system against her actual activities at concrete moments. She interpreted the non-wearing of the brace during certain activities at certain events (dancing at a birthday party) not as a sign of non-compliance; rather, recounting the event and the activities served as an index for her inference: there is room for excuses, for a re-evaluation of what counts. It is a refusal to conventionalize calculating time according to a metric device (for a further discus-

sion on refusal and resistance to numbering practices in evaluating schools' performances see Gorur, 2018).

Yet it is not a refusal or resistance to the device and the monitoring and visualization of hours worn per se. Children and teenagers embraced the idea of the monitoring system, they enjoyed accumulating kittens; most importantly, it enabled them to quantify and visualize what is otherwise hard to grasp. Having to count the hours one wears a brace (with many forgetting at some point that they are actually wearing it) is a challenging learning process. The question is how to integrate the monitoring system's symbolic numbers and one-many generalizations with the young patients' calculation practices and their microworlds. Obviously, an important empirical part is still missing here: the routine use of the system. What kinds of effects might emerge with the use of the system?[13] Verran would offer the right tools for carefully dissecting how the different modes of generalizing wearing-times encounter each other in everyday routines, how they possibly create frictions, merge and/or subordinate each other. I could speculate on what might happen if the monitoring system gets implemented, but cannot make an empirically sound claim. However, I insist on the potential of the chosen analytical tools not only in hindsight, when we can actually observe the workings of such systems in people's lives, but also to problematize the potential implications for the future. Juxtaposing the calculations of time worn based on my account of children's and teenagers' mundane calculative efforts with the development of the monitoring system, backed up by the feedback of the participants of the observational study, enabled me, for example, to propose an additional visualization of wearing-time to the development project. While children and teenagers embraced the kitten-version of the feedback, providing them with a time line similar to a school timetable would assist them in their struggles to achieve the advised hours and multiply the indexical range. Yet this small pragmatic supplement leaves a central problem untouched.

The incremental processing of deductive inference through the monitoring system will potentially have an amplifying effect as it reinforces the logic of psychological assumptions about rational choice and decision-making, medical assumptions about numerical evidence and evidence-based interference, and techno-scientific assumptions about the neutrality of mathematical and technological data processing. As I have shown, producing deductive inference is not a straightforward process, but messy work distributed between human and non-humans. The potential decontextualization of compliance and the reduction of compliance to absolute numbers are not produced "by the algorithm". Rather we have to pay attention to the configuration of numbers as symbols, with deductive inferential profiles, working as one-many relations, to potentially reinforce each other and make the case for only one logical way available to treat the issue at hand. As these numbers are created not only for inferring conditions from physical parameters within expert systems but with the intention to conventionalize mundane numbering practices such as those of the young patients, we need to carefully attend to the work done in the production of such unambiguous numbers and to their capacity to transform ontologies.

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NOTES

1 For a further discussion of these concepts see Verran (2012: 66). For a further classification of the interpretants (or 'significate effects') see also Lalor (1997).

2 It would be a misinterpretation of Verran's work to suggest she does not incorporate this potential gradual shifting and transforming of numbers. She points to this rather briefly in *Science and an African Logic*, where she describes numbers' relational capacity to "seamlessly connect" and "recursively juxtapose[s]" between various entities such as "a child sleeping on his mother's back in Ibadan with the ledger of the British Empire" (Verran, 2001: 100). In an example of the computerized processing of numbers into a hybrid of symbolic/iconic manifestation, she hints at the implications of model-based automated numbering processes (Verran, 2013: 31). Yet the overall focus in her work lies elsewhere, as discussed above. Overall, to elaborate a recombinant of the two analytic tools hinges on their principle potential connectivity to produce any combinatory benefit.

3 Note for example his attempt to synthesise in one article (Kockelman, 2011) what he calls biosemiosis, technocogniton, and sociogenesis, with examples as different as animal-signals systems and natural selection to lawn mowers and Turing machines.

4 In recent years there has been increased interest among scholars of STS on studying algorithms; for a critical discussion of what can actually be considered an algorithm and what it means to take algorithms as objects of analytical attention see for example Dourish (2016), Gillespie (2014), and Ziewitz (2015).

5 For a discussion (or mediation) of Kockelman's work as "transacting ontologies", also in contrast to other takes on ontology in anthropology, see Bill Maurer's review in HAU (2013).

6 The regional innovation cluster "BeMobil: Regain Mobility and Motivity" was funded by the German Ministry of Education and Research. The cluster focused on the development and improvement of rehabilitation technologies and therapeutic systems for patients with limited mobility after a stroke or due to amputation or scoliosis. For more information see http://www.ige.tu-berlin.de/bemobil/parameter/en/

7 In the lab situation, the system actually captured data more closely; e.g. temperature and humidity every five seconds. However, during the observational study with teenagers using the system "in the wild", data was captured every five minutes. The latter seems to be a more likely final solution, mainly due to storage capacity and energy supply. The underlying logic however – summing up intervals versus passage of time – remains the same with five seconds or five minutes.

8 Compared to the complex examples and hybrid numbers Verran is elaborating on in her numerous examples, this is a rather simplified elaboration of her concepts and arguments.

9 In a sense the intervention is rather symbolic, as there is no effect other than the numbers appearing on the display. In principle, the monitoring system addresses a self-reflexive subject, one who changes her or his behaviour based on the numbers. Yet in everyday life the brace-wearer and the monitoring system are not isolated from social worlds, where parents, but also therapists and – even though only once or twice a year – doctors, comment on these objective, technically produced numbers and participate in this new regiment of compliance. In what way the system will actually intervene cannot be answered at this point.

10 Cf. to Paul Kockelman and Anya Bernstein's (2012) work on time reckoning, with a systematic description of the portability of measuring systems.

11 He leaves aside the most common transformativities usually addressed in social sciences and anthropology: the speech act and the looping process (cf. Kockelman, 2013: 45-49).

12 But which sensors and what data? Actually, the answer to this question was part of the development process: Which (combination of) sensors will produce data that leads to the most robust mode of inference? And what is the relevant inference? And also more technical questions: How could they be attached to the brace? What about storage? Yet, even though this "relatively abductive phase" in the development process was an important prerequisite for the further development of the system and shaped machine learning in a fundamental way, for reasons of comprehension and space, I decided to leave this part out and start in the lab.

13 One could also draw directly from Peirce's concepts and differentiate between different interpretants generated by the use of the system. Peirce (1974 [1906]: 326-327) elaborated different interpretants: from the "emotional interpretant" evincing an emotional response (remorse, frustration or satisfaction maybe), the "energetic interpretant" to a "habituated response" (e.g. the number on the display triggers a certain change in performance, such as putting the brace on when the number was not yet high enough). Peirce's work offers a variety of ways of differentiating the potential effects of the system and I thank the anonymous reviewer for making me aware of this rich potential.

On Not Muddling Lunches and Flights: Narrating a Number, Qualculation, and Ontologising Troubles

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Abstract

Calculating and making public carbon footprints is becoming self-evident for multinational corporations. Drawing on ethnographic data I narrate of the calculative routine practices involved in that process. The narration shows how routine yet sophisticated mathematical transformations are involved in retrieving salient information, and second that mathematical consistency is readily interrupted by 'dirty data'. Such interruptions call for opportunistic data management in devising work-arounds, which effect enough mathematical coherence for the number to hold together. Foregrounding an episode of calculative data retrieval, interruption and work-around contrivance, I employ it to make a comparative reading of two STS analytics, arguing: whereas Callon and Law's (2005) analytic technique of qualculation reveals the episode of data management and work around contrivance as a teleologically oriented process that manages to bridge mathematical inconsistency, Verran's technique of ontologising troubles enables us to recognise how a number-as-network configures its particular kind of certainty and coherence, how it sticks.

Keywords: calculation, number, ontics, ontology, qualculation, empirical philosophy

Introduction

Number studies thrive in Science and Technology Studies (STS). STS has raised a range of questions challenging numbers and calculation. These include how chance got quantified and politically employed (Hacking, 1990; Desrosières, 2002), how accuracy gets constructed (MacKenzie, 1990), how trust in numbers is playing out in society, technology and economy (Porter, 1995) or how equivalences are achieved (Espeland and Stevens, 1998; MacKenzie, 2009a). The concerns here are not about numbers as output of some calculation, but rather about how numbers and calculations are employed in practices that constitute science, technology, economy—such as knowing epistemic objects (Knorr Cetina, 2002), distributing resources and accountabilities (Strathern, 2000), constructing economic agents (MacKenzie, 2009b), setting prices (Fourcade, 2011) or defining baselines (Ureta, 2017).

The field of actor-network theory (ANT) has been highly instrumental in STS for studying material and semiotic entities as relational networks (Latour and Woolgar, 1986; Latour, 1987; Law, 1992, 2009). ANT studies of numbers and calculations have opened up how accounting numbers configure action at a distance (Robson,

1992), how markets get materialised (Callon, 1998; Callon and Muniesa, 2005) or how collateral realities get enacted in presenting quantifications (Law, 2012). In the latter cases, numbers and calculations, too, are analysed as components of semiotic and materials relations that configure science, technology, economy. ANT's power to open up entities as relational networks, however, has not been deployed to open up specific numbers, numbering or calculations. Two notable exceptions are Verran's (2001) work on doing numbers in routinised practices and Callon and Law's (2005) proposal to study calculations as interwoven with judgement, using the neologism of qualculation.[1] Callon's (1986) concern with numbers can be traced back to his work on scallops and their conservation at St Brieuc Bay, Law readily shares how he learned it from Callon (personal communication), whilst Verran (2001), disconcerted by her experiences of learning and teaching numbers and basic concepts like length in Nigeria, set about delving to the insides of numbers.

The subfield which this paper operates in, then, is the use of ANT to open up the networks *within* numbers or calculations. How to use ANT to explore this opening? A number of ANT authors point us to ANT not as a consistent body of theory but rather as something akin to a toolkit (Latour, 1996, 1999, 2005; Law, 2009; Verran, 2007b). I wonder, then, whether the tools to open up numbers and calculations are equivalent, lend themselves to the same kind of work. And, I suppose, this concern and question is relevant to others who want to understand, master or even deploy the toolbox of ANT to open up numbers. The research question of this paper then is narrow and has a methodological form: how do the two analytical framings, qualculation and Verran's take on numbers, differ, complement or work against each other? This question matters not only for enriching our understanding of the ANT toolkit's inner compatibilities and frictions, but also to the larger task in STS of spelling out the nuances between some of its analytics.

The question, and the research to address it, is novel in that it positions the reader to engage in a comparative methodological exercise. This means that this paper focuses on studying how the two analytics work, in analytic practice. In short, this paper presents a study of two ANT techniques. Both these techniques are key for ethnographic investigations of a number-as-network. To study number-as-network this paper employs a method of empirical philosophy, narrating a number.

What both analytical approaches share is that enumerated concepts, results of calculative and quantifying relations, have 'insides'. This follows from a core claim of the ontological commitment in ANT to the mattering of material, bodily and semiotic practices (Verran, 2001; Callon and Law, 2005; Law, 2009): doing numbers or calculations enacts not only the known but also the knowers.

The argument pursued here is that both analytics narrate and analyse numbers/calculations differently, foregrounding different relations, elements or effects of the insides. This means that the objective is to show that both approaches lend themselves easily to make different points. This does not rule out that both approaches could be mobilised to say what the respective other is saying, too. The point I want to draw out is that each approach makes some things easier and other things more difficult to explicate. And, unsurprisingly, both approaches have not been very explicit about what they tend to fore- or background. So, the contribution to STS which I pursue is to show how these two ANT approaches, though similar, are also different, and not easily substitutable against each other.

The empirical ethnographic material that I draw on in narrating a number deserves an introduction as much as the choice to use precisely this material. The domain in which the number/calculations I am interested in have been practiced, is the field of carbon numbers and economics (Callon, 2009; MacKenzie, 2009a; Lohmann, 2009; Lovell and MacKenzie, 2011; Ehrenstein and Muniesa, 2013; Vesty et al., 2015; Lippert, 2016). Specifically, I turn to carbon accounting and bookkeeping, numbering and data practice. This ties in with an analytical trajectory that investigates how environments are known and come into being through data, information, algorithms, simulations, databases and reporting—configured into situated practices of environmental management and sustainability governance (Elichirigoity, 1999; Waterton, 2002; Fortun, 2004; Ellis et al.,

2007; Millerand and Bowker, 2009; Edwards, 2010; Gabrys, 2016; Lippert et al., 2015; Blok et al., 2016).

I studied carbon accounting in a financial service provider, one of the globally 50 largest companies (by revenue). This was an ethnography conducted across 20 months, studying the multinational's environmental management work with a focus on their material and semiotic practices through which they achieved their global carbon footprint.[2] Opening up numbers of carbon accounting involves addressing their indeterminacies and certainties.

To open up number-as-network, I tell a story of a number, which has been configured, *inter alia* by myself, the corporation's sustainability accounting database, a subsidiary's chief operations officer (COO) and a worker who put environmental numbers together for him. The worker, Nick, figures key in my narrating. Most relevant for the present paper, Nick was a novice—first-time user/practitioner—of doing environmental data for the company. Studying a novice promises to disclose the frictions and work involved in doing numbers (cf. Suchman, 2007: 122). Neither Nick nor his boss, the officer, were concerned with explaining or theorising numbers, data and calculations, not with experimentation for making carbon markets work (Callon, 2009). Still, my narration of the number includes a calculation. And this calculation was highly effective as a machine that made the corporate carbon accounting exercise proceed, a machine that made things work, enriching the voluntary carbon market, rather than standing in the way (on machines and their working, see also Lippert, 2011; Neyland, 2018, in this special issue).

Next, I offer some notes on methodology and transparency. Then I turn to the core: I narrate a number in a way such that the two analytics can be deployed; subsequently I introduce the qualculation analytics, putting it into practice by analysing a calculation. Then I present the Verranian analytics and use it to ontologise a number's troubles. Finally, I draw together my conclusions in terms of the two analytical approaches differently oriented capacities to foreground specific workings within numbers or calculations.

Methodology

This paper is grounded in an ethnography. The workers I studied knew I researched them; and I was employed to support the company in optimising their environmental accounting database. To protect informants, I render names anonymous, numbers imprecise and convert currencies into EUR.[3]

This paper's methodology takes the form of empirical philosophy, rather than of systematic qualitative data analysis. Following the purpose of the present special issue—interrogating recent innovations in STS analytics of numbers and numbering (Lippert and Verran, 2018)—for my analysis I have constructed an empirical story that serves to interrogate STS analytics. The narration, or story, here is not shaped to meet specific sociological and ethnographic criteria. Storytelling serves here to allow the reader relate and attend to key empirical detail, strengthening my ability to respond to the troubles I identify in and around Nick's calculation (on response-ability, see Haraway, 2016; on storytelling as relational practice Kenney, 2015: 758–759). The story is not narrated to privilege a particular explanation, attempting, drawing on Benjamin (2006), even to keep it free from explanation. This choice of methodology suffices to draw out the generativities and limitations of particular STS analytics.

The empirical story I present is bundled with inferences that draw out the significance of some of the relating that shaped the calculation or took place within the latter. To be able to analyse the practical, epistemic and ontological work in doing the calculation, I use the mathematical genre as a device: I employ mathematical denominations and equations that the numbering and calculation practice explicitly referenced or implicitly postulated. Using the mathematical genre stays true to some of the forms of rationality that I identify in Nick's practice.

A concern with accurate description or grounded theorising would shift the focus away from the kind of empirical philosophy I undertake. The evidence presented within the empirical story may be understood as serving a part-whole generalisation (Winthereik and Verran, 2012)—the kind of numbering and calculation I analyse is part of the company's global carbon footprint

and involved in relations to governments and investors, i.e. global political economy. One limitation of the kind of empirical philosophy I conduct is that this paper in isolation cannot make claims about the majority of calculations I have studied. The empirical story in this paper, if read in isolation, must be understood as an artefact of being written to serve the methodologically interested interrogation of the two ANT analytics.

For the purpose of comparative methodological analysis, I offer an interested presentation and deployment of both approaches, mediated by a partial reading of both, Verran (2001) and Callon and Law (2005). Whilst this constitutes another limitation of this methodology, an exhaustive review of the authors and their approaches is beyond the scope of this paper and not needed for the purpose of the comparative exercise. To respond to the research question, it suffices to identify differences between both approaches that are salient to the empirically grounded data and inferences that I narrate.

Narrating a number

The multinational's accounting database, accessible as a Lotus-Notes based application in the corporate intranet, included forms, suitable called 'task forms', which subsidiary environmental agents were tasked to fill (as an illustration, view the form for reporting water consumption, Figure 1). I wanted to learn about the ways data gets constructed. My own boss at the headquarters (HQ) allowed me to travel to a Western Asian subsidiary, study their environmental data practices, and she tasked me to support subsidiary staff. So, off I went, arrived in the megacity, housing the multinational's regional sub-HQ. On my second day

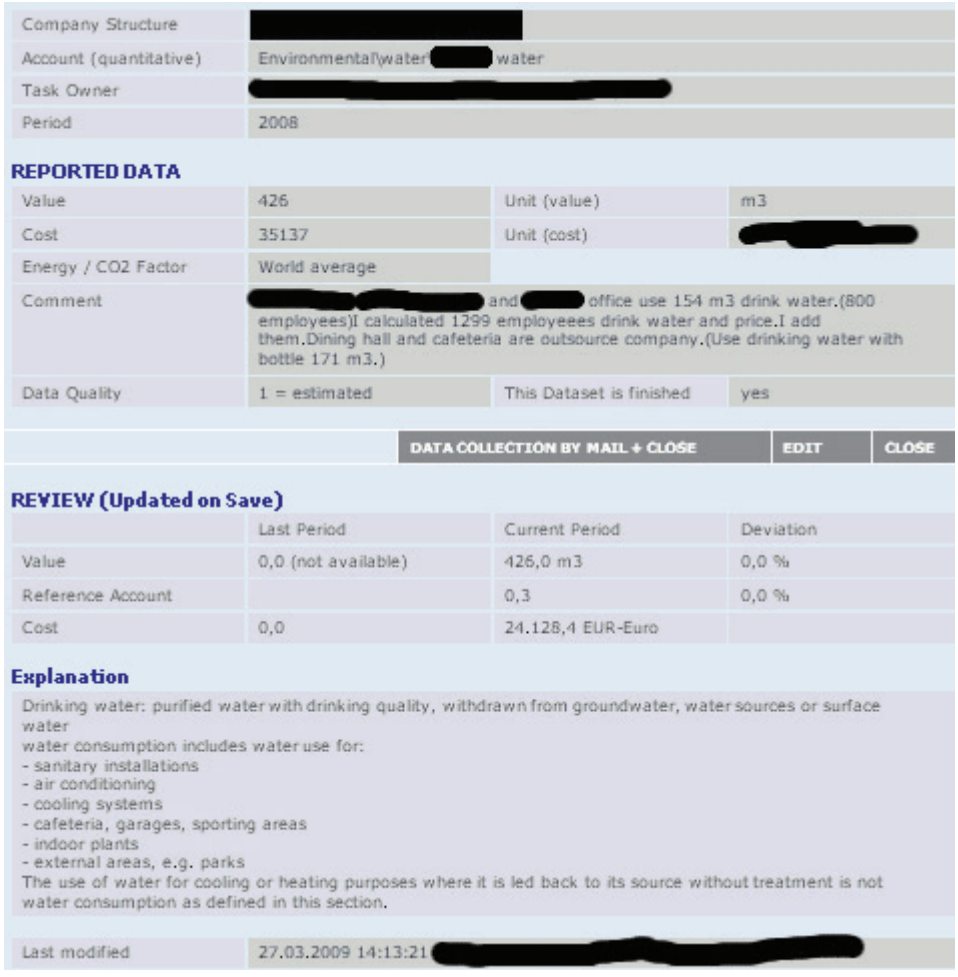

Figure 1. 'Task': General form for environmental data entry (this screenshot documents Nick's form use to report 2008 drinking water consumption; for the respective analysis, see Lippert (2016); Source: Lippert, 2013: 81)

in the city, after a bus tour on a hot summer day, through the Eastern parts of the city, and then into the better neighbourhoods, finally I arrived at the modern steel-glass block. I entered the building, was asked whom I wanted to see, and after some back and forth was led to the subsidiary's COO. He occupied a large office, with a glossy wooden desk and several square metres of windows at the top of the building.

Early in our meeting Nick Xi joined us and presented a list of numbers to hiss boss, the COO. Later on I learned: Nick was the office site's head engineer, a novice in environmental accounting. Nick had been asked to retrospectively collect the 2008 environmental data that the HQ was seeking. Subsequently, Nick showed me around at the site, and, eventually, we went to his office, located in the building's windowless basement. His work space was neighbouring round six other desks. Nick and I soon got to work in depth, me doing participating observation and helping him out, clarifying things when he had questions, and Nick drawing together various environmental data. We worked, and worked, and, let me fast forward, to the next day of working with Nick, he sitting on his red chair, and me at his beige desk on this Friday afternoon, directly after lunch, between 2–4pm, in spring 2009. His desk was set up with two land line telephones, a computer screen, mouse and keyboard.

Nick picked up the phone to ask a colleague about the distances travelled by staff of his company. In the conversation he learned about the costs incurred in the prior year for domestic flights, 168,078 *EUR*. This phone conversation made him laugh and smile. His work equipment included a paper, to note the numbers and to conduct some simple calculations, like additions, multiplications and divisions. He next divided the flight cost number by 230 *EUR*, an average cost of each flight, and multiplied the result with 500 *kilometres*, an average distance crossed with domestic flights. With the result of this calculation ready, he turned to his computer and entered the result in the 'task' form for reporting the distances travelled on short-haul flights. At this point I intervened, suggesting to Nick to also briefly describe in the form's comment field how he had calculated the estimation. He hesitated, but then agreed.

Five inferences bring out the richness of Nick's calculating, mixing the ethnographic with the mathematical genre. Nick mobilised the total cost fact for the calculation. Where did this fact come from? Picking up the phone, Nick had called a colleague and received the cost fact on domestic flights for the subsidiary. This is not trivial. And this is the first inference. While for this particular case he managed to 'immediately' access such a cost fact for the totality of the subsidiary, with other environmental indicators he had to struggle more. For instance, Nick was also to report his subsidiary's water consumption data. Yet, some of his subsidiary sites did (or could) neither fully report water costs nor the consumed amounts. So, Nick extrapolated the available site-specific consumption facts to the scale of the subsidiary, with calculations, materially supported by spreadsheets, pen and paper. Luckily, for calculating flight distances, Nick was equipped with an already complete fact; no need to extrapolate towards the total costs at subsidiary level: at the end of his phone call, thus, he laughed and smiled.

Knowing that the organisation had paid 168,078 *EUR* for domestic flights did not tell him how many kilometres have been bridged, however. Nick reconstructed the cost fact corresponding to a particular mathematical form, my second inference: as the *sum* of several individual flights, totalling *n* flights, each with a cost, c_n. He effectively exploded one number into many.

$$\sum_{i=1}^{n} c_i = total\,costs$$

Equation 1

Unfortunately, Nick had not received information, at this point in time, about each flight's associated costs, c_1 to c_n; all the individual costs were as unknown to him as the number (*n*) of and distances (d_1 to d_n) travelled with flights. From observing Nick exploding the total cost fact and transforming it into the cognitive form, shown in Equation 1, I infer, thirdly, that this cognitive understanding inspired Nick to use a mathematical routine, well known to him, that would allow ignoring all these unknowns. Thus, Nick explicated assumptions about these individual flights, specifying each flight in two dimensions, in terms of estimated average values: one for the cost, $\bar{c}_i$

, and one of the distance of an individual flight, $\bar{d}_i$. For instance: 'I assume, on average a domestic flight bridges a distance of 500 kilometres and costs 230 *EUR*.' Mathematically, he postulated $\bar{c}_i$=230 *EUR* and $\bar{d}_i$=500 *km*. To be even more explicit, these assumptions implied:

$$\frac{\sum_{i=1}^{n} c_i}{n} = 230\ EUR$$

Equation 2

as well as

$$\frac{\sum_{i=1}^{n} d_i}{n} = 500\ km$$

Equation 3

And, Nick knew what he was searching for: the total distance travelled by short-haul flights, sum of all the flights' distances, $\sum_{i=1}^{n} d_i$. My fourth inference is then: making such assumptions, when equipped with the total cost and searching for the total distance travelled, presented Nick with a clean structure of statements (illustrated by Table 1), leaving only one unknown element, the quantifier *x* for the data type *total flight distance* in *km*.

Nick treated this frame of triples with only one unknown as mathematically exploitable, my fifth inference. He identified the two repeating units, *km* and *EUR*. Dividing the average distance travelled per flight by the the average cost of a flight, and multiplying the result with the total cost fact, Nick could cancel out the two *EUR* units, resulting in a data point with the unit *km*.

$$\frac{EUR}{EUR} \times km = km$$

Equation 4

This is the corresponding mathematical form:

$$x = \frac{\sum_{i=1}^{n} c_i}{\bar{c}_i} \times \bar{d}_i = \sum_{i=1}^{n} d_i$$

Equation 5

In a differently plain language, for the qualitative STS scholar:

$$x = \frac{total\ costs}{average\ costs} \times average\ distance = total\ distance$$

Equation 6

And this is the calculation:

$$x = \frac{168{,}078\ EUR}{230\ EUR} \times 500\ km = 365{,}387\ km$$

Equation 7

Despite the more or less overwhelming mathematical richness, Nick swiftly and seemingly routinely solved the problem of the missing data point and entered it in the short-haul flight accounting form.

Entering data into the environmental database was part of a routine of what the headquarters (HQ) called 'environmental data collection' in the company. The collected data was reviewed at the HQ, checked for inconsistences or obvious errors, followed by possible corrections. All the unique data points, indicating the consumption of water, electricity and paper as well as the distances travelled and the amounts of waste disposed, were multiplied with specific factors that converted each data point into the amount of carbon emissions (CO_2e) resulting from the respective consumption.[4] For example, according to standard conversion factors, short-haul flights cause higher emissions, per kilometre, than long-

Table 1. Structure of statements.

Knowledge status	Framed triples of data			Math.
	Quantifier	**Unit**	**Data type**	
Partial	*x*	*km*	total flight distance	$\sum_{i=1}^{n} d_i$
Complete	500	*km*	*average flight distance*	$\bar{d}_i$
	168,078	*EUR*	total flight costs	$\sum_{i=1}^{n} c_i$
	230	*EUR*	average flight costs	$\bar{c}_i$

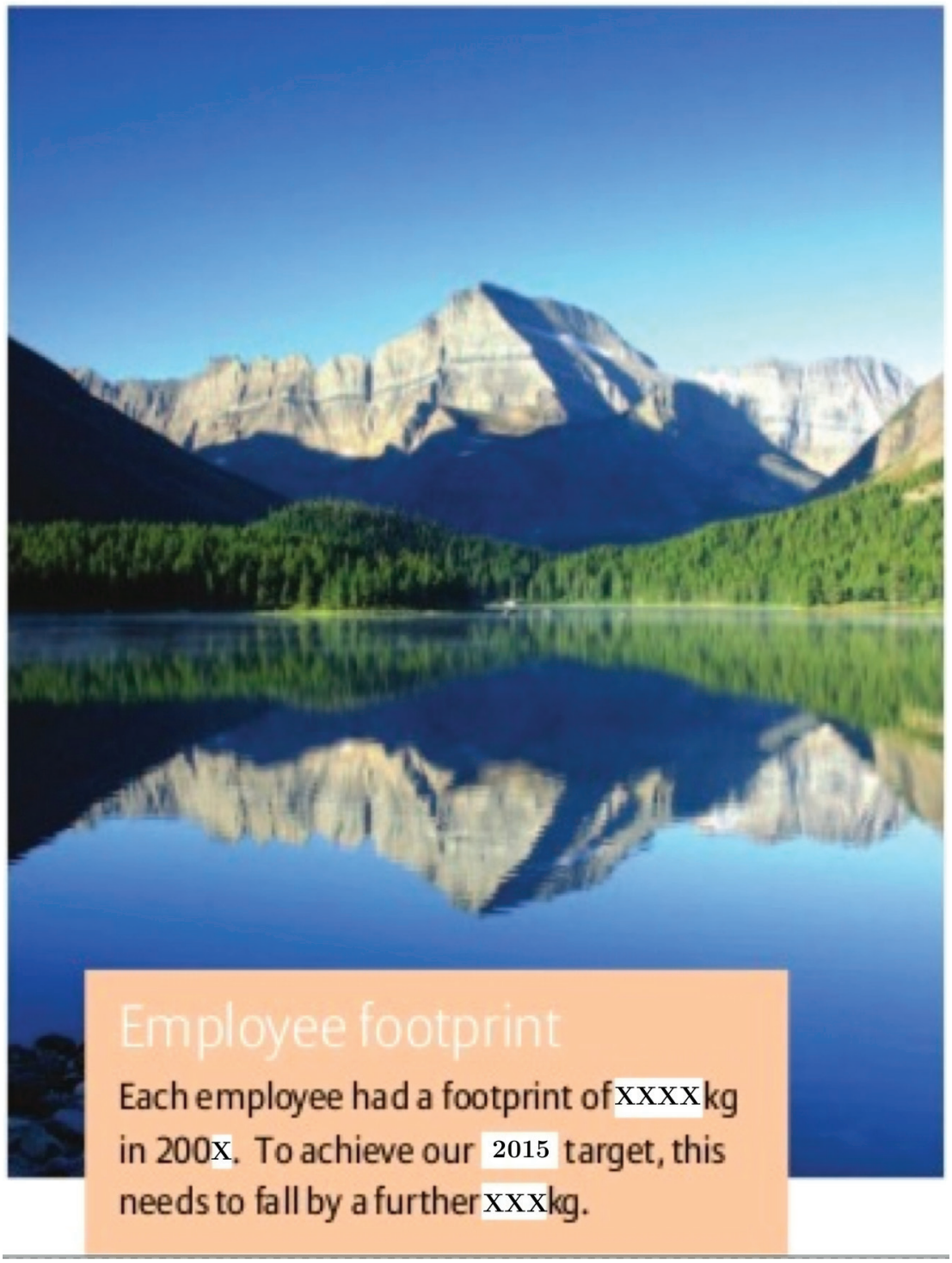

Figure 2. 'Employee footprint', extract from the corporation's Sustainable Development Report (Source: Lippert, 2013: 206).

distance flights.[5] The amounts of emissions were then summed up into a carbon footprint reported on a balance-sheet, for each subsidiary as well as for the global operations of the multinational. This footprint was communicated to stakeholders, including auditors, partners, investors governments and civil society organisations, for instance in the form of relating last year's (2008) average carbon footprint per employee to the target of emission reduction in the future (2015), as illustrated in Figure 2.

Later the afternoon, Nick received an email that contained a spreadsheet. The latter detailed which cost items have been part of the account for domestic flights. The list included diverse items such as flights, restaurant visits, trips by boat and taxi and visa fees. He called out: The list includes lunch! Despite the skilled mathematical routine, it seemed clear the data could not be used. And so it proved.

Before the workday ended, Nick and I went to see Nick's boss. In this meeting we talked through a range of uncertain issues (that are not at the centre of this story), which Nick and I had encountered. In his reaction, the boss made one point very clear: he demanded Nick to only report facts; no insecure estimations! A few days later the comment Nick had originally added to the flight data had disappeared; and the distance itself had decreased to 60 percent of the distance Nick had calculated earlier.

What has happened, to summarise, is that Nick was tasked to report short-haul flight data. This data did not exist. So he contrived a work around, employing mathematical routines to retrieve the data he was to report. This work around contrivance drew on domestic flights' cost data and Nick used his calculation's output as input to the short-haul flight reporting form. Yet, later, Nick realised that his mathematical 'trick' for recovering distances from the domestic flight data would not work well because the cost figures included other costs that go along with staff taking flights—like buying lunch during the journey! The data was dirty! Eventually, Nick's subsidiary had reported a lower figure. I was not there to observe how precisely this has been derived but I suppose that Nick withdrew the 'non-flight' cost items from the total cost fact of the domestic flights sum (data cleaning). And I know that Nick's subsidiary did not posses distance data. Thus I infer he was otherwise going through the same series of mathematical assumptions and calculations. Closing off, as instructed he did neither draw attention to this 'internal adjustment' nor the assumptions in the short-haul flight reporting form. For the purposes of this paper, I end my narration here—though of course the story continues, elsewhere. It is this episode in the 'doing of this number' that serves the purpose of comparing STS number analytics. And, thus, I turn now to analysing this episode.

Qualculation

This section re-presents the qualculation approach, deploys it to re-narrate numbers, mathematical forms and a calculation and, at the end, draws out what I discern from this deployment about the qualculation approach in practice. I argue that the qualculation approach lends itself to foregrounding how a calculation achieves a form that effects connection, in this case securing quantitative calculability despite mathematical inconsistencies.

Borrowing the notion qualculation from Frank Cochoy,[6] Callon and Law (2005: 718, 722) argue for dismantling the dichotomy between the calculative and the noncalculative, instead positing both as mutually constitutive: the very distinction dissolves when we consider a boundary as achieving both, one side and its Other. Positively speaking, they use the notion qualculation to suggest that calculation and judgment are interwoven. This interwoven character comes to the foreground in their thinking of calculation as a 'three-stage process'. This process can be read and deployed as a robust instrument, as evidenced in this special issue by Gorur (2018), Holtrop (2018) and Neyland (2018). In this section I primarily focus on this qualculation process as an analytic instrument and deploy it, subsequently analysing what the instrument foregrounds.

> First, the relevant entities are sorted out, detached, and displayed within a single space. Note that the space may come in a wide variety of forms or shapes: a sheet of paper, a spreadsheet, a supermarket shelf, or a court of law—all of these and many more are possibilities. Second, those entities are manipulated and transformed. Relations are created between them, again in a range of forms and shapes: movements up and down lines; from one place to another; scrolling; pushing a trolley; summing up the evidence. And, third, a result is extracted. A new entity is produced. A ranking, a sum, a decision. A judgment. A calculation. And this new entity corresponds precisely to—is nothing other than—the relations and manipulations that have been performed along the way. (Callon and Law, 2005: 719)

My partial reading of Callon and Law elaborates this three-stage process. Core to the first stage is the existence of entities that are disentangled from other relations, rearranged and by that ordered to fit a space. In that respect, the first stage needs to be considered as performing a relational and categorical shift: the entities' connections are severed and they come to fit into the boxes of specific sorts. Within this space, in the second stage, these entities are rearranged by positioning them into new relationships between each other. The authors address these relational changes as manipulations and transformations of the entities themselves. In the final stage, out of these rearranged entities, a statement is drawn ('the result'). They plausibilise their generalisation by referring to several versions of such spaces and transformations: For the supermarket and the trolley, consider Lave (1988) and Cochoy (2008), for the court of law Latour (2009) and for sheets of paper and spreadsheets Lippert (2015).

Callon and Law (2005) specify their model in several ways. I identify two larger points. First, they clarify that the entities, 'objects', are manipulated 'within a single spatiotemporal frame' (Callon and Law, 2005: 719). True to post-ANT considerations, they suggest that the entities do not preexist their framing. The framing shapes the object; making entities fit the box, the order, constitutes new entities. In short, with Mol (2002), the framing enacts its objects. And framing comes with overflows, all that which does not fit in (Callon 1998). Qualculation as enacting new entities means also that the practice of qualculating is both, material and semiotic. For that they point to, *inter alia*, 'paper and pencil; the benches in a court of law; a system for tallying arrivals and departures' (Callon and Law, 2005: 719). Each of these frames and framings comes with specific spatiality and temporality; their shapes and topologies are potentially indefinite. Enacting any particular form takes time, is work, is an achievement. The effort consists of disentangling entities from others, removing and adding relations.

Second, I propose, Callon and Law (2005) model qualculation as intentional action—between the lines. In a summarising sentence, they suggest that qualculations "are all about arraying and manipulating entities in a space *in order* to achieve an outcome, a conclusion" (Callon and Law, 2005: 719, emphasis added). Thus, qualculations come with a purpose, i.e. a *telos*; they are practices for the purpose of producing their result. When the two authors turn to addressing the modes and practices of achieving non-qualculability,[7] they engage with Quaker worship and agapè as "strateg[ies] of *calculative rarefaction*" (Callon and Law, 2005: 723). Common to both are intentional practices of being passionate. "The Quakers have a set of material and discursive practices *for* disentangling from qualculability. *For* losing themselves in the passionate" (Callon and Law, 2005: 722, emphasis added). The disentanglement is purposefully produced in material and discursive practices. This analysis of resisting qualculability resonates, for the authors, with Power's (1999) take on accountability in 'audit society'. Making accountability is work, and so is making unaccountability (Callon and Law 2005, 725; see also Gorur, 2018, in this special issue). Achieving unaccountability is tough. I read their model of (non) qualculation, then, as purposeful action, in which actors or strategies are directed towards results, using resources to achieve these results. Whilst their analysis is not limiting qualculation to intentional action, all their cases involve intentional actors, trying to achieve particular (un)accountabilities and (non)qualculabilities.

To put the instrument of qualculation into action, I distil from the prior discussion the following questions: by which configuration of material and discursive practices do actors achieve what kind of simultaneously qualculative and non-qualculative space? How has Nick actually managed to produce this agencement which we tend to refer to as calculation? What do we grasp by analysing this as a mathematical operation? Conceptualising this set of relations, this movement of signs, as a mathematical office operation suggests that all the entities involved in it are unproblematic; we grasp it as a rule-following method, an implementation of the rules of multiplication and division. This understanding misses the practical point of the operation: it was not about solving a mathematical problem but about bringing into reality an entity that before had not existed. Thus, Nick's practice had a transformative character: it altered the form of how these entities existed; he assembled them in a shared plane in

which he conducted the operation. This transformative movement deserves spelling out.

In what follow, I map the three stages by Callon and Law onto my narration of Nick's calculation and numbers. According to qualculation's first stage, Nick had to initially sort out and detach some entities that he could work with. The total cost fact, which he had received, was already of a sort that he could employ well. This, however, was not self-evident. In the cases of several other environmental key performance indicators, Nick had not received total cost facts, but had to construct those.

Yet, whilst Nick was able to employ the total cost fact, in isolation the fact did not suffice. Nick next created further statements that effectively reconstructed the total cost fact via a mathematical form: as the *sum* of several individual flights. This reconceptualisation expanded the possibility for calculability. He could now make assumptions about these individual flights—he defined the average cost and distance travelled per flight. The postulations depicted in Equation 2 and Equation 3 mean that Nick judged his assumption of the two averages, $\bar{c}_i$ and $\bar{d}_i$, to be sufficiently equivalent with the real flights costs and distances (textbook mathematics, in contrast, would require some form of signifier like standard deviation to specify the degree of equivalence). Nick's judgement was relevant to bridge the gap between the different sources of information, the phone call's provision of the total costs versus his own experience of flights. In this moment he used situated judgement about these relations, I presume his local knowledge of distances and flight costs in the subsidiary's region of operations, rather than documented traces that might have established a link between the averages and the individual flights' distance/cost facts. These interwoven judgements, bridging the gap across the two different kinds of sources, are by no means self-evident. Politics and economics, in particular cost-benefit analysis, recognise the significance of this kind of treatment, calling it commensuration (see Adorno and Horkheimer, 2006: 13–14; Porter, 1995: Ch. 4; Patterson, 1998): "Commensuration transforms qualities into quantities, difference into magnitude." (Espeland and Stevens, 1998: 316)

And the accounting database form made clear what he was working towards: the total distance travelled, in km, for which he lacked the quantifier. Thus, at the outset, here, we can identify four statements (one given fact, two assumptions and one searched for result, the partial statement). He had, thus, disentangled the total cost fact and the body of flights these costs represented into four statements and drew all these statements together. With Callon and Law (2005: 719) we can think of his practices as sorting out and detaching these statements from the wide range of data held by financial accountants and of the possible assumptions he could have made. They call this process *qualculation*, underlining the involvement of judgment and qualification with quantification and calculation. The qualification here consists precisely in performing these statements and relations as appropriate rather than others. Not only could the assumptions have been different (such as specifying the average distance or costs with other quantifiers) but also could have the statement structure been alternatively configured (in fact, below, I introduce how Nick later challenged the structure himself). The selection, thus, of precisely these statements created and prefigured a space in which the subsequent calculation had to take place.

Now that the relevant entities are enacted and detached from another, they need to be "displayed within a single space" (Callon and Law, 2005: 719) to conclude qualculation's first stage; the space of these four statements needed to be transformed to perform in two ways: first, the space needed to allow for calculation and, second, the calculation's results needed to fit the material structure of the company's environmental database, i.e. its data entry form (cf. Figure 1). Thus, again, the accounting form guided Nick in how he worked. This form required the total distance travelled by short-haul flights to be represented with specific qualifiers and quantifiers: these included, first, the quantitative 'value' of the flight distance (i.e. the number) and the 'unit' (kilometres), second a 'value' and a 'unit' of corresponding costs and, optionally, a qualitative 'comment' on this particular data set. A possible inscription structure that prepares this list for calculability is to reimagine/rewrite the statements as *triples*. The calculation which Nick eventually performed, thus, corresponded to a three-fold structured space, depictable as a table (illustrated by Table 1). This space is marked with

a boundary of in/exclusion: to be excluded were the traces of the statements' sources. The fact that some statements were assumptions got lost in the framing—Nick was focused on the numbers.

With this first stage of organising qualities and quantities, Nick achieved new entities: once in the table, flights and costs existed in the shape of numbers, units and categories. The table itself framed these shapes in particular ways. The qualities of framing extend from the design of the data entry form to Nick's preparation of data for that form. Thus, the entities drawn together by Nick were transformed and changed shape; the resulting objects did not preexist their framing. Those qualities that did not fit in, are the overflows that Callon (1998) addresses: making things calculable means framing them and that necessarily implies that some things do not fit the frame and flow over the frame.[8] The boundary-drawing performs a qualification of how numbers are present in this space. Nick's employment of the framed triples (in Table 1) shows that he is precisely not just dealing with hypothetical, in an undeconstructed sense, 'numbers' but with interwoven qualities, categories and units. The triples do not prepare some 'calculation' (in an undeconstructed sense) but a much more specific qualculation.

This selection, positioning and framing allows for the second stage in the qualculation process model: to actually informationally treat the four statements in relation to each other. Nick related the costs of all flights to the average cost of a single flight. This means he treated these kinds of costs as being of an equivalent quality. And he handled the average distance of a single flight as qualitatively non-distinct from the sought for total distance travelled. In both relations, he treated the two statements related as quantitatively different, rather than qualitatively. Nick achieved quite simple arithmetic relating—an ongoing relation—that took the form presented in Equation 6. Stage two of the qualculation instrument, points us, thus, to the calculative machinery, the central component of the equation:

$$\frac{total\,costs}{average\,costs} \times average\,distance$$

Equation 8

Without structuring triples in this way the information would have been different. In this mathematical form, the entities of the table are rearranged so that they appear simultaneously qualitatively and quantitatively compatible, thus, calculatively relatable. Now, consider Nick's judgement that his structure of treatment was apt. This is a key qualification, underwriting the calculative machinery, a second commensurating move.

Finally, in the third stage of the qualculation process, the arithmetic practice mathematically related the three framed triples, shown in the middle column of Table 1. These three triples were solved for the one remaining unknown with Equation 7, producing a result, 365,387 *km*, effectively a fourth triple: a) the value/quantifier 365,387, b) the unit *km* and c) the category total flight distance. This result was, importantly, technically compatible with the accounting short-haul flight reporting form's field for numeric input, and its option to select km as a unit, and this is a point I come back to. To summarise, Nick related the triples that he heaved into this space in a way that allowed him to produce a result for the unknown slot. With this calculation he produced the fact, the very data which he was to report. Nick, thus reported through the database environmental data that he first had to bring into existence in a thoroughly qualculative performance.

This story of qualculation nearly gets slightly messed up when we consider the spreadsheet that Nick received in the afternoon. Some of its elements threatened to undermine the calculability, which Nick had so routinely achieved and we have so painstakingly adumbrated. Nick made judgement about these troubling entities of the spreadsheet. I never did learn what precisely happened subsequently. I can only report that, eventually, this Western Asian subsidiary reported a smaller sum; the total distance crossed by means of short-haul flights was reduced. Nick effectively managed to avert the threat to calculability: he delivered a result to the headquarters. Yet, the spreadsheet did not detail the distances travelled by each domestic flight, d_1 to d_n.

Zooming out, one further calculative-qualifying move comes in light. Lingering between the lines so far, Nick's task was to fill the form for the

indicator short-haul flights, *y*. Following Callon and Law (2005: 719) '[t]hings have to qualify before they can enter a process of qualculation'. Nick's qualculative practice performed the domestic flight cost data, *x*, which he received, and subsequently employed in his arithmetics, as qualifying for the short-haul flight travel account.

$$total\,distance_{domestic\,flight} = total\,distance_{short-haul\,flight}$$

Equation 9

$$x = y$$

Equation 10

Nick, practicing this qualculation, could be certain that his work of slipping and connecting was organisationally appreciated—contrasting with Coopmans' (2018) analysis of the trouble of workers who have not been managing to solve a disconnect through clever numbering. Nick employed his judgement and calculative routines making *x* fit the form of *y*, even if this final slippage in reference was collateral, a 'collateral reality' (Law, 2012) of inserting the quantifier for the domestic flight data in the form for short-haul flights.

The mathematical tension here did not concern Nick. Whilst multiple interpretations are possible, Nick situationally judged well, that his achievement of connecting sources to the data form would not generate organisational tensions but, rather, comfort (on comfort, see Pentland, 1993).

What do we learn about the instrument of qualculation? By way of rethinking Nick's work as qualculating, we overcome the misleading dichotomy between calculation and judgement. In actual practice they overlap. This is no news to accounting scholars (e.g. Pentland, 1993; Robson, 1992). The point was not only to demonstrate a case of qualculation. I am concerned with analysing the apparent ease of a calculation—of a class that was not at all exceptional, but was and is exercised, constantly, ubiquitously. Defamiliarising such a calculation is a hard case.

The qualculation approach is generative in that Callon and Law's (2005) take translates the hard defamiliarisation task into a quite simply procedure, consisting of the three stages. These were quite straight forward to apply. This approach allowed us to identify the entities employed by Nick and helps us see their saturation with politics: at several moments other qualifiers and quantifiers, other structures and moves of relating them, could have been opted for. Qualculation, then, seemingly offers an instrument for analytically narrating; we get a well-tellable story in which even the challenge to calculability eventually disappears when the qualculation's *telos* is realised in the reporting of a result to the HQ.

Core to this style of qualculation analysis is that it generates a story of Nick as intentionally treating the data in a way to achieve a number that can be plugged into[9] the multinational's central environmental database. Nick had started out with one determinate entity, the total cost fact, and rapidly conjured up further claims that turned into certainties in their tabular formation and were enrolled in the equation form to solve for his target not-yet-determined number, the total distance travelled by short-haul flights. I applied the qualculation analytics and found it to guide me in narrating of progressively more determinacy along the stages towards the result that Nick achieved. Determination, then, characterises both what I analysed and how I analysed it. Indeterminacy is first solved, and when new indeterminacies cropped up in the form of unwelcome content of the spreadsheet, these were overcome. In sum, Callon and Law's (2005) approach is generative of a story of a directed chain of enactments with the clear target of dissolving indeterminacy: the solute of indeterminacy changes its visibility, rendered invisible in the fact delivered to the HQ.

Callon and Law's (2005) qualculation approach configures a narration that conveys how (non) qualculability is achieved and secured. The qualculation instrument is generative of foregrounding how connections are made, relations established, in order—intentionally—to effect either qualculability or non-qualculability. Callon and Law are fittingly quite concerned with differentiating strategies to achieve these. This instruments' focus on strategies to achieve either, qualculability or non-qualculability, establishes simultaneously a dichotomy—collateral damage?

The approach does not encourage me to analyse and attend to the fascinating fastidiousness and assiduousness of Nick, his practices of

making things very clear, reading the spreadsheet in detail, cleaning up data, indicating how he got to his fact in a comment and deleting it, attending to some of the data troubles. Maybe because these are not central to his practices' telos, securing qualculability? But they seem to be important elements in shaping these calculations and the mode of qualculability. Yet, these are neither about (non)qualculability nor the measurable degrees thereof. Whilst the authors, Callon and Law, surely have capacity to engage with these elements, their three-stage approach of qualculation and the strategies for achieving (non)qualculability do not lend themselves to open up these elements. In fact, Callon and Law (2005: 724–725) position qualculation as Other to the space of (pre)trust, care and agapè.

How then did these elements matter? I suspect these are about qualities of relations of accountability and I am disconcerted about their (missing) relevance in the qualculation analytics' study of the incremental crystallisation of the reported data on short-haul flights as certain.

Ontologising troubles

Nick did not voice troubles, but my narration does. Does it matter that Nick offered a comment, like in the centre section of Figure 1, deleted it and cleaned up the data? In introducing this section's deployment of Verranian analytics, and with Verran (2001), clearly, yes, it does. It does matter because the comments' explication of how Nick had calculated the result as well as the sorting out of inappropriate elements, i.e. data cleaning, involve commitments to, or explications of, what these data are. So Nick had faced ontological troubles which he engaged with by deleting the comment and cleaning data. Verran (2001) would point to *Science and an African Logic*, Mr. Ojo and herself, ontologising troubles in the classroom.

In turning to Verran's work, I am not renarrating what the qualculation analytics was able to scrutinise. Instead, I deploy her work to attend to how it comes that the mathematical inconsistency, troubles, in the work achieved did not shatter Nick's qualculation. I argue that Nick ontologically accomplished a calculation that achieved a configuration of certainties, in plural(!), that sufficiently cohered, allowing the result to stick. Cohering elements contribute to amassing certainty, despite mathematical inconsistency. This section brings forward, and then alter-ontologises, the troubles in Nick's work. Ontologising, then, is the instrument I draw from Verran. To continue, I initially introduce Verran's take on ontology as practice and subsequently deploy it to analyse a subset of relations of the number-as-network.[10] I close this section with a reflection about the way Verranian (re)ontologising foregrounds elements and relations in enumerated entities.

Practicing a form of juxtapositioning that does not privilege Western or Scientific standards, Verran offers a form of empirical philosophy that draws on engagement with both indigenous community as well as western science and technoscience. To start in the middle, consider her book's end in which she calls for "telling of the rituals and the coparticipants, human and nonhuman, living and nonliving, in microworlds, as reliable ways of managing complexity" (Verran, 2001: 238). In order to narrate and ontologise Nick's, or my, troubles, we need a sense of her notions of microworlds and ritual.

I consider counting objects like books a repeated routine performance. Verran (2001) calls such performances microworlds, or micro-worlds (Verran, 2002), based on Rouse's (1987) work on laboratories. She specifies microworlds as materially and semiotically configured time-places featuring routinising practices of interrogation, naming and tracking, effecting the boundaries of stuff, rather than passively reading preexisting entities. In such a microworld, the exclusion of irrelevant complexity is similarly routine. Microworlds produce realness. She highlights the reoccurring character of microworlds, repeatedness, routine and ritual, with her concept of clotting. "An object clots when the repetitions and routines of its generating microworld become a ritual." (Verran, 2001: 162) The repetitions and re-performances in ritual-like ways pre-figure and pre-script and, thus, stabilise their objects, gradually and relationally coagulating the objects and its shape. Normally, the case of counting routines is safely ignored, leaving the material and semiotic processes of clotting specific numbers often invisible (Verran, 2007a: 37–38).

She develops these considerations in *Science and an African Logic* and proposes that in the very practices of counting an object not only is the number performed but the object too. Following her approach, the pure matter of, say, books when we count them is not antecedent to the action but is brought into reality in that very performance. Face your distributed bookshelves; any count is an outcome of relational practice involving nonliving participants, e.g. paper and digital entities, living like ourselves, counting some entities as books, a multi-volume work as 1 book, excluding others. Being certain of the count emerges within doing counting, that is in the acting within a relationally configured situation. The bookshelves in my study room surely can be assessed as complex; but more importantly, the narration of the number at the core of this paper clearly shows the simultaneous simplicity and complexity *within* Nick's qualculation.

More importantly than the degree of complexity—numbers, numbering and how certainty is embedded within them appears, in the Verranian approach, as an effect of particular situated relating. Drawing on her work amongst Yoruba children learning calculating, she proposes: "Certainty of numbers is an outcome of the routines by which they are constituted in collective acting" (Verran, 1999: 150).

Her approach does not limit itself to numbers, but explores more widely what, and how, things are. This she calls ontological investigation (Verran, 1998) or empirical ontology (Verran, 2005). Core to this approach is to "refuse any and all *a priori* separations" in relational practices, characterising Verran's (2005: 42, her emphases) take as monist, whilst narrating things, society and nature as effected in those practices.

Core to the instrument of ontologising is the analytical division of labour between two narrations:

- **Ontic narrations** refer to 'the level of entities' existence or being' (Verran, 2007a: 34), i.e. realness, where entities are to be understood as actor-networks, that are accomplished, performed in material-semiotic practices that include our practices' (not necessarily explicit) commitments to these entities being there.[11]
- **Ontologic narrations** are characterised by explicitly explaining, studying or theorising what is and the metaphysical commitments to what is; this ontology is materially-semiotically performed and, thus, may shape reality-making.[12] Ontologising, however, does not necessarily determine its object, the reality being enacted.

To deploy this instrument, I narrate two disconcertments that the qualculation instrument did not easily allow me to story. Firstly, I turn to cleaning data, and, secondly, to the comment.

Lunch! Whilst the qualculation approach was able to register that data cleaning took place, I sense a richness in the moment of Nick receiving the spreadsheet and recognising the range of non-flights inscribed into the domestic flights account. Nick calling out 'lunch!' only made sense in relation to the spreadsheet that included a line, implying that some lunch cost had been part of the accumulated flight costs. In this evocation, then, Nick indexes the spreadsheet's lunch line. This specific line troubled Nick. Lunch was out of place. This implies that Nick was committed to the sort of things that would be correctly listed in the spreadsheet. He was concerned about the wrong entity being in the list. This means, Nick was able to draw a border between different categories, marking some as not fitting with the category of flights. Lunch was easy. Taxi costs more difficult, because they were clearly part of the overarching key performance indicator 'travel', of which 'short-haul flights' have been part. Evidently Nick was exercising a logic of what flights are. Lunches *are* not flights.

With Verran we can call Nick's practice of storying lunch as not being a member of the category flight as doing ontology. Nick ontologised flights. Lunch in the flight account troubled his ontology. Interestingly, before Nick got the spreadsheet, he was not troubled by the lunch line yet. That is because he was enacting the flights differently then, with a different ontology, an untroubled one. The flight data, before the spreadsheet, were practiced as pure flights. Flight data after the spreadsheet was impure. His ontologising had shifted.

Nick must have noted then that the flight data body he was working with was different from what

he felt committed to. He had been doing a reality all along, ritually, over the many steps I narrated above, an ontic practice, that was committed to including the original domestic flights' total costs in deriving the total distance travelled by short-haul flights. So, whilst his practices were committed to enacting short-haul flights all along, after reading the spreadsheet, he nuanced his allegiance, his commitment.

Cleaning data, eventually effecting a smaller total distance fact, was enacting then a different ontology, to which his practice was committed, a smaller *x* inserted into the form of short-haul flights. In this ontology lunches are not flights, and routinely *x* equals *y*, as an ontic effect, domestic flight data remains slipped into the account for short-haul flights.

In the microworld of Nick 'gathering' data and entering that into the central database's forms, numbers were part of clotting several data sets, just like the short-haul flights. These clots have been stabilised. That we assess the short-haul flight fact as being erroneous does not (seem to) affect that this subsidiary's 2008 data has been maintained and employed by the corporation for many years. To my knowledge, the multi-authored, with Nick as a core author, clot continues to be enacted as part of the historic, this subsidiary's baseline, data of environmental impacts.

Now, on to the second disconcertment. When Nick had first entered the result of his calculation I had asked him to enter a comment on his calculation in the data entry form. He then had described in the comment field how he had gotten to the total distance fact (to illustrate, see the comment section in the entry form, Figure 1). By offering this comment he offered a trace of what his fact meant, effectively telling a story about what his number was. Simultaneously, this established the fact as troubled because it was not a straightforward fact, speaking securely for itself. I suggest this kind of storying work can be considered an ontological practice because it explains what the number of the total distance crossed by means of short-haul flights consisted of.

In the conversation with Nick's boss, Nick was told to only report facts; no insecure estimations. In tension with this demand, his comment did point to the two estimations involved in the calculations, the average distances and costs, $\bar{c}_i$ and $\bar{d}_i$, qualifying the total distance fact as a calculated estimate, not securely signalling factishness. The explication of trouble got, thus, troubled, and troublingly the trouble got hidden: a few days later the comment was deleted. The numbers without comment showed no trace of their history anymore, no contingency, no trouble.

What did deleting the comment do to emissions? A data set that came with a comment was signalled to the database user at the headquarters and prompted them to review that data set. Trouble! This algorithmic function served to support the system in achieving accountability. It was considered necessary by the system designers because the company recognised that sometimes numbers required some explanation; numbers did not always tell all relevant stories on their own. Comments, thus, enriched the ontology of environmental data, by serving as unstructured metadata. Without comments, those data users who had no direct contact to the agent-entering-data had less chance to actually learn about some of the considerations around the numbers reported. Yet a different form of trouble. Simultaneously, no comments also meant that superiors were less likely getting back to the bookkeeper to inquire about the data reported. Less of this trouble, at last. Both effects altered accountability—however, in different ways. In a Strathernian/Harawaynian twist, we could voice: it matters what troubles trouble troubles.

I understand the information reportable in comments as a partial account of the modality of the numbers and units reported in a form. Such modality was co-constitutive of the numbers. Bookkeepers were responsible for the data they entered. For the bookkeeper, deleting the comment also implied that they alone carried the possibility for responding to questions on data. Providing a comment extended responsibility materially to the database. The data set could respond directly to questions. A response-*able* data set was also a risk, however, because it could answer to questions without the bookkeepers' control. Deleting a comment made the data less accountable and reciprocally reduced the risk of having taken the work situation out of the worker's control. No risk that the data set

would speak against the bookkeeper, no risk that the comment would raise undesired concerns or questions about the number's straightforward story.

This shows that offering the comment qualitatively enriched ontologising the commented data and the reality of flight distance; and second, that opening up the ontological shape of what the data supposedly represents emerges as a risk. Without comment, ontologising for actors (other than Nick) was much more speculative—definitively differently grounded, if not less grounded—for they only encountered a straightforward fact, no detour via uniquely authored metadata, con-text. No signifier of trouble.

This seemingly straightforward fact was enrolable with less friction in a range of ontologies. Precisely because the numbers were not accompanied by explicit stories, the numbers lost their ability to resist arbitrary stories that would refer to the fact. Whilst the straightforward fact appears intuitively more certain, it emerges in my analysis as rather indeterminising.

Verran's instrument of ontologising and attending to ontological practice helps foregrounding the range of potential stories about what is the case, the range of storying reality, how troubles trouble. This analysis in terms of ontologising troubles indexes a complicated space of responsibilities and accountabilities. I propose that Nick's data submission mattered in two key ways. (1) Nick seemed to care for giving a good (enough) account of the flights. For that he edited the data after having received the spreadsheet that had included, in his reading, non-flight costs, indexing his data sources 'better', cleaning up data. This qualification work involved ontological considerations by Nick about what was not to count as short-haul flight costs, such as lunch costs. However, his explicit ontologising did not range into reasoning how domestic flights mapped onto the company's definition of short-haul flights. Thus, his routine calculation approach to translating domestic into short-haul flights remained stable. Ontics does not determine ontology. (2) Further, he wanted to complete the data submission without problems—and his boss had troubled the friction caused by qualifying data as estimated. Correspondingly, deleting modalities became a solution. These two ways were not overly coherently aligned to one another. None of the actants involved dominated the relations around the data submission with a singular strategy. Much rather, this work space needs to be understood as ordering in multiple ways—situated doings that were both materially-semiotically ordered and in which actants enacted a non-deterministic order of the flight fact. Precisely because the comment got deleted the resulting data was interpretable in more ways.

The matter of the reported total short-haul flight distance of Nick's subsidiary, thus, was not precise and stable. By way of staging the flight fact as simple, his 'simple' practice effected flight-matter with less stable meanings and as a less fixed reference point compared to to upholding his indexing comment. Indeterminacy multiplies. The simplicity allowed more readings of and, thus, workings with the numbers. Removing the grounding of ontologies multiplies the space of narrative possibilities. Thus, the configuration of bookkeepers, the central database and headquarter staff achieved a world of flight matter that was loose, connectable to all kinds of other entities, and not explicitly referring to the multiple material-semiotic doings in which practices and entities were ordered and performing order.

I turn now to analysing this narration of the ontological significance of providing and deleting the comment as well as of cleaning up data. It has deployed a Verranian attention to actors (re)doing and not-doing ontology, generating a space of multiple stories of how the comment-in-relation mattered. This instrument of re- and alter-ontologising foregrounds relations and configurations of accountabilities, certainties and indeterminacies.

Deploying Verran's ontology in this way performs ontologising ethnomethodologically. Using ontology involves a form of accounting. And these accounts can come with a range of temporal orientations. An ontological enactment may attempt to prefigure some practices; and in the very moment of ontic practice (e.g. Nick doing flight data, first-time-reading the spreadsheet), ontological reflection about these practices may take place (lunches are not flights); and doing ontology may as well relate back in time to offer a retrospective retelling about reality that, of

course, joins in shaping the present. With respect to versions of the past, I am reminded of the retrospective telling of plans, that always differs from situated actions, simultaneously offering a new account of reality-making joining in semiotic reconfigurations (Suchman, 2007). The realness effected in some material-semiotic practice may be reconfigured in material change and semiotic shifts over time—as in when a number sign that was accomplished to signify a specific reality is read differently, through another ontology. The ability for retrospective retelling and rereading allows the Verranian instrument of ontologising to account for members' storying of realness where members' own stories may gloss over, sidetrack from or even highlight relations between signs—such as categories, units, number words and rules—or logics of how these should relate. Ontologies of reality multiply because it is not an antecedent reality that determines how the reality is theorised, but ontologies are enacted in time-places, and tomorrow's ontology might be as different from the current as the ontology of a differently positioned actant in the present.

Following this consideration of troubles and multiplicity, I suggest that we can consider the use of this analytics as yielding several political troubles: in this analysis of narrating a number-as-network, I opened up the politics of undoing modalities of claims and the trickiness of what it means to get the job done. Contrasting the troubles with the punctualising (Law, 1992) characteristics of technologies of, say, policy recommendation bullet points for evidence-based governance, Verran's analytics is generative of stories of so rich realness that explodes punctualisation attempts, rendering her analytics rather compatible with anti-hierarchical politics, such as workplace resistance in the midst of global environmental accounting. Spelling out an ever-dynamic partial and situated realness-in-the-making is *unlikely* to travel well in the universe of evidence discourse—hegemonic policy circles.

My Verranian-inflected account of a number's metadata contrasts with the ease in which Nick's numbers could circulate within the company and plug into the multinational's global carbon accounting. Deleting the comment altered qualculability not in degrees but in kind, rendering the carbon accounting machinery more smooth, removing merely a tiny obstacle to it running well. This Western Asian subsidiary's short-haul flight distance number became part of not-so-earthly machines of references in emission trading. Nick's practice did not only effect collateral realness, but collateral certainty, too. Above we had identified that Nick was positioned to be certain that his slippery commensuration of domestic flights with short-haul flights would be organisationally appreciated. By attending to the space of storying around the comment the Verranian analytics foregrounds how certainty that the reported fact is straightforward is conjured up.

The corporation, too, was positioned through the enactment of the total short-haul flight distance to be certain that these short-haul flights existed. Whilst conjuring up out of costs a quantity for short-haul flights, these flights are enacted along the way as much as the certainty that they exist at least in so far that they do not resist their enactment. And deleting the comment helped reduce resistance. For the user, whether in the corporation's HQ, its civil society or regulatory counterparts, the situation appears straightforward: "I read short-haul flights, I include them in my assessment, therefore I can be certain they exist." Certainly, we are encountering here the multiplicity of certainty.

Conclusion

Narrating a number opens up possibilities for analysis that reveals worlds in the process of being made. This paper presented 'narrating a number' as a method of empirical philosophy. Narrating a number is generative of a narration that includes description and inferences. Here, the description is ethnographically derived. Description and inferences together ontologise the number. This method allows investigating the number-as-network. Narrating a number, then, shows what is inside the number, what it is made up of, how it coheres and relates.

This paper conducted a two-fold exercise. First, it narrated and analytically renarrated a number, and its constituting calculative practices, explicating worlds being made—the case here shaping the world presumed in environmental

economics—emissions. Assembling emissions secures the demand basic to carbon markets. Second, it analysed how two analytical approaches within the field of actor-network theory—Verran's (2001) take on ontology and Callon and Law's (2005) three-stage process of qualculation—differ, complement or work against each other.

With their shared commitment to reality emerging in material-semiotic relating, both analytics are well positioned to agree with, or complement, each other. Comparing them indicates three sets of results.

First, as analysing numbers and calculations is discursively positioned in relation to competing formalist discourse, such as mathematics, it is relevant to note that both qualculation as much as Verran's empirical ontology allow for inconsistency to be part of numbering and calculating. While in qualculation analytics inconsistency may be encountered, its mattering is second to the achievement of (non)qualculability and their respective securing of a result or the impossibility to draw out results. Verranian ontologising turns to how reals emerge, encourages attention to elements and practices, independently of how coherent they appear, and this may result in attending to entities and relations which the qualculation take does not need to generate a neat qualculation narration. Thus, whilst I find the commitment to material-semiotic relating shaping objects and worlds to be shared by both analytical approaches, what the approaches invite attention to is not equivalent.

Second, what these analytics foreground, is methodologically differently configured. In narrating a qualculation, I find myself positioned to reconstruct a quite linear temporality, prefigured by this analytics' three-stage process. Verran's ontologising invites narrating of ongoing relating. The latter can be quite disorienting, but also generative in turning to practices' multiple relations of accountability, backwards, forwards and sideways in time. The (non)qualculability attention appears as a focussing apparatus, singularising concern: which of either form of qualculability is achieved? Verranian ontologising, in contrast, appears as an instrument that guides puzzling, exploring troubling, maybe well described with Haraway's (2016) quest to 'stay with the trouble'.

This leads to the third point: While narrating a number through the qualculation analytics, I am repeatedly provoked (as some of the reviewers, too) to feel consternated: $x = y$, this can't be! This approach seems to invite a form of external critique, In contrast, in ontologising troubles, I identify a form of infracritique, attending to collective accomplishment, multispecies co-authoring and wonder. Verran might call this exploring disconcertment.

I conclude that these two analytics offer useful instruments, and that both of the analytics' instruments are not equivalent in that they do not foreground and guide attention equivalently. Thus, declaring the use of the ANT toolbox to open up numbers is not sufficiently specific, for it matters with which commitments the scholars prepares and analyses the material.

Venturing into prescriptive number analytics methodology, I suggest as criteria for narrating number: The narration needs to take a form such that a number's worlding, relating, ontic and ontological commitments can be analysed, as much as the frictions, gaps or disconnects between material, epistemic or logical entities or relations as well as the directedness of calculative processes or their meandering and swaying in social-material space.

Along this narrative analysis, a final point crystallises—on numbers. Narrating a number explodes the number, for the number's inside is relating in multiple ways to outsides. The inside/outside dichotomy starts to collapse. Instead of presuming where the boundary of a number is, it seems now apt to analyse the boundary-making of how numbers are made to, or seek to, be different to non-numberly space. We can also follow how numbers are enacted, singled out, or qualculative relations. Maybe provoked by qualculation's thesis that quantification and judgement are interwoven, and sensitised by Verranian attending to ongoing relations by heterogeneous co-participants, number is denaturalised as much as pushed to the analytic margin: relations of qualifying need as much as attention as relations of quantifying. Yet, even more focus needs to be redirected to the multiple relations of connecting and disconnecting, relations of account-abilities and response-abilities in networks that are

glossed with a shorthand as 'number'. Such redirection of concern in numbers studies might be called 'after numbers', for here we study what is within the number-as-network as much as, in a different topology, behind number signs.

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Notes

1 Asdal's (2008) work, too, is relevant for ANT takes to open up numbers. However, in this paper, I want to focus on ethnographic, rather than historiographic, approaches.

2 The narration that I pursue here is not shaped to reconstruct a case of carbon management accounting. I do present such a case, explore it in the political and economic context, including relationships to stakeholders and standardisers—e.g., GRI reporting demands, the WBCSD, a global nature conservation NGO—elsewhere (see Lippert 2013, 2015, 2016).

3 Detailed methodological outlines of the study and its generalisations are available (Lippert 2014).

4 On the relations between the concepts of carbon, CO_2 , and CO_2e, see Lippert (2012).

5 The conversion factors differ because in short-haul flights the emissions resulting from take-off and airport infrastructure relative to the emissions by a plane flying in 'parallel' to earth's surface is larger than in long-haul flights (326g versus 180g per kilometre) (see Lippert 2013: 101).

6 Cochoy introduced the notion in 2002, see Cochoy (2008).

7 Gorur's (2018) contribution to this issue further nuances and enriches Callon and Law's (2005) take on non-qualculability.

8 Economists refer to this move as externalisation. More specifically, however, I identify a form of internal externality: the project of internalising environmental consumption facts folds into itself the externalisation of the statuses of these particular environments (cf. Strathern 2005).

9 On plug-ins, see Latour (2005).

10 For a more elaborate re-reading and contextualisation of Verran's work, consider Kenney's (2015) contribution.

11 See Verran 1999: n.16; 2001: 116–118; 2005: 42; 2007a: 36.

12 See Verran 1999: n.16; 2001: 118; 2005: 42; 2007a: 34; 2009: 5, 17; Verran and Christie 2007.

6.15%: Taking Numbers at Interface Value

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Abstract

This article discusses a number, 6.15%, as it comes into being in the course of an evaluation study of education in a southern Afghan province. This number indicates that out of 100 school-aged girls 6.15 go to school. While this kind of number may invite reflections on its epistemic accuracy, more often it draws attention to its inherent negative — the girls that do not go to school — substantiating a need for sustained international commitment. As this article will show, numbers work to establish girls as research entities, as part of populations, and as a concern for the Afghan government and the international intervention. This interfacing work of numbers — between girls, states, interventions, and research protocols — is often absent from academic work that takes numbers to be stable and passive tools with which the world can be known. This article, instead, takes numbers to have an internally complex multiplicity and to actively engage with their environments. In this article, I use the interface between numbers and environment as a space for ethnographic exploration of world-making. By describing three moments in the lifecycle of the number — data cleaning, analysis and presentation — I describe three distinct moments of interfacing in which the number comes to act in three capacities: effecting reference, constituting proportional comparison, and evoking doubt and certainty. Detailed understanding of numbering practices provides an opportunity to not just critically assess numbers as end products but to carefully assess the worlds that emerge alongside numbering practices and the ways in which numbers contribute in processes of governance.

Keywords: numbers, referentiality, percentage, proportionality, certainty, doubt, Afghanistan

Introduction

In 2013, NATO and the US troops were about to draw their 12-year military presence in Afghanistan to a close, Afghan and international audiences, policy makers, academics, journalists, and aid workers were asking the question whether or not the intervention had been successful. In a piece in the New York Times (NYT, 2013), Vanessa M. Gezari boiled the international difficulties in Afghanistan down to one issue: American soldiers fail to understand Afghans. As a successful intervention relies on good intelligence this is a problem. Gezari, therefore, called for a renewed involvement of anthropologists, whose core skill is to understand across cultural, linguistic, and social borders. These anthropologists would be able to help decipher Afghan metaphorical and allegorical conversation, full of parables and jokes that "[are] nothing like the Excel spreadsheets and acronym-heavy briefing slides that military people are trained to read." (NYT, 2013).

The contrast that Gezari evokes is a classic one. The straightforward world of Excel — the numbers

Working Excel Sheets in Afghanistan

										Boys		
GPS	MoE School Code	Picture code	NO	Name of School	Teachers in area that do not teach	Reason I for not teaching	Reason II for not teaching	Reason III for not teaching	Reason IV for not teaching	Total	Attend School regularly	Attend School occassio nally
	0		24	Attachement of Babur Quli School								
	0		25	Malizai Sufla	0	0	0	0	0	88	53	22
	0		26	Sarkham Ulya	2	low salary	have other	0	0	114	81	23
N .32.62848-E.065.89783	0	29	27	Sola Koochian(Koochian Sola)	0	0	0	0	0	119	84	15
	0		28	Nawabad Koochian School	2	low salary	have other	0	0	61	0	0
N .32.63043-E.065.91003	0	30	29	Sarchakhli Girls(Naswan Sarchakl	0	0	0	0	0	0	0	0
N .32.63158-E.065.89927	0	28	30	Sarchakhli Boys(Zkur Sarchakhlai	0	0	0	0	0	89	66	12
	0	24	31	Jangi Kariz	0	0	0	0	0	142	113	16
	0	16	32	Sadmurda Ulya	2	low salary	threats	0	0	65	46	9
N.32.1231-E.065.93015	0		35	Garmab Sufla	0	0	0	0	0	221	185	14
	0		36	Shna Wala								
	0		37	Charamgar(Neswan Charmgar)	0	0	0	0	0	0	0	0
	0		38	Sajawal	5	threats	0	0	0	151	0	0
	0	13	39	Sadmurda(Sadmarda Sufla)	0	0	0	0	0	95	0	0
	0		40	Markazi Madrasa								
	0		41	Haram Shah School								
	0		42	Sinan School	0	0	0	0	0	90	0	0
5m N32.53760 – E065.676	0	11	43	Mir Baba(Kata Khanjak Mirbaba)	0	0	0	0	0	92	73	14
	0		44	Wani School								
	0		45	Sabzabad	0	0	0	0	0	54	0	0
	0		46	Kata Khanjak Madrasa								
N.32.36.736-E.065.53.464	0		47	Darululum	0	0	0	0	0	347	298	37
N.32.63066-E.065.87344	0	21	48	Sidal Khan	21	low salary	have other	0	0	1625	1488	77
	0		49	Sidal Khan								
N.32.63161-E.065.87994	0	19	50	Sidal Khan	33	low salary	have other	0	0	1487	1356	59
	0	17	51	Kootwal	5	low salary	have other	threats	0	631	571	44
	0		52	PED								

Figure 1. Part of Excel sheet used in the evaluation of education in Uruzgan

that fill them and the briefing slides — cannot grasp the supposed Afghan mystery of hidden meaning and non-literal messages. Instead, what is needed is serious investment in anthropological, imaginative inquiries. This contrast renders the Afghan more exotic, while Excel sheets and indicators become more unremarkable. What would happen, however, if we shifted our anthropological attention to the Excel sheets and let ourselves be riddled by their numbers?

Between 2010 and 2011 I worked as an evaluator trainee for an Afghan research organization. This Excel sheet (Figure 1) was the main tool for an evaluation study of education in the Southern Afghan province of Uruzgan. The Dutch embassy had commissioned this study as part of a larger evaluation of its military and developmental presence in the province between 2006 and 2010. It was going to be an important moment in the public communication of the intervention's achievements to Dutch constituencies.

The number I trace is 6.15%, a percentage that offers information about the number of girls going to school in the province. It is supposed to reliably convey the fact of girl students' attendance in Uruzgan, but, as this article will discuss, there is more to the process of numbering and the facts it produces. I could have taken any number, but this one was of special interest to the donor. It was a crucial motivator for the intervention in Uruzgan, a place described by many Afghans and internationals as a place of extremes even in a country like Afghanistan, which is commonly associated with political excesses and material scarcity. Here are some conventional figures and faces that appear in the reports and works on Uruzgan (Beeres et al., 2012; Bergen & Tiedemann, 2013; Dam, 2014; The Liaison Office, 2010). Uruzgan is known as the "recreational" ground of the Taliban — a place where they rest and gather their strength before and after the spring offensives. It is both the birthplace of the Taliban's former spiritual leader Mullah Omar, and the place from which former president Karzai rallied support to push the Taliban from Kandahar in 2001 and claim the presidency in Kabul. In addition to its putative historical importance, Uruzgan is viewed by many to be the most economically and educationally backward province in the country. Illiteracy numbers are widely reported as the highest in the country and are often correlated to Uruzgan's high incidence rates of domestic violence. As it happens, Bibi Aisha, whose disfigured face featured on the cover of Time in 2010 and became the global icon of Afghanistan's brutal treatment of women, is an Uruzgani native. According to international organizations, progress on the path towards democracy and stability is hampered by

tribal conflicts, opium production, and insurgency networks, all of which add layers of instability and violence to this province that is politically and socially quite distant from the national capital of Kabul. By most developmental indicators, Uruzgan was a place that urgently needed intervention and it was in 2006 that a joint Dutch and Australian task force took up NATO's assignment. The Dutch ended their military mission in Uruzgan in the summer of 2010.

The evaluation study commissioned by the Dutch was going to be done by the Uruzgan team, of which I was a member. The European woman who had co-founded our organization was also the supervisor of this evaluation project. She had translated the donor's interests and questions into questionnaires. As Uruzgan was heavily Taliban controlled, it was impossible for non-Uruzganis to collect answers to these questions. For this reason, local surveyors did the work. Our team subsequently flew to Uruzgan to debrief these surveyors and collect the paper forms that they had filled out in the local Pashtu language. Our Afghan project manager processed all the answers that specifically dealt with education by transferring the information from the paper forms to the Excel workbook of which the above image is a screenshot. In the process, he translated a diverse series of answers and figures to a more or less standardized format in English.

After entering all this data, we were left with a workbook that was grotesque in form and content: it was made up of several sheets with endless columns and rows, all sorts of color coding, empty or filled cells, and mixed Pashtu and English language and numerals. It stored a vast range of characteristics of schools and schooling: GPS coordinates, village location, educational level, information about schools being closed or open, types of subjects taught, number of teachers officially assigned to the school, number of teachers actually teaching permanently or temporarily, their gender, the number of teachers in the district that do not teach, why this was the case, the official student count, the number of children that occasionally or regularly attend school, their gender, the construction status of school buildings, the number of used and unused rooms for boys and girls, the presence of a boundary wall, latrines, wells, hand pumps, kitchen facilities, textbooks, the quality of those facilities, type and amount of threats to teachers, students, or schools. These characteristics appeared on the horizontal axis, labeling the 98 columns that qualified the list of schools that appeared on the vertical axis, which in turn labeled the rows. Each separate spreadsheet of the workbook dealt with the schools of one district, and as Uruzgan has seven districts, the workbook contained seven spreadsheets.

My supervisor asked me to start with the analysis of the Excel sheet. In the days that followed I tried to decipher the Excel workbook and figure out how to analyze it and what order or trends I could discern from it. Thus far in my academic or professional career I had never learned how to use this software, understandably to the disappointment of my supervisor. As I couldn't tackle the database and still had to produce an overview of educational developments in Uruzgan, I decided to fall back on my anthropological training, put the quantitative aside and craft a qualitative narrative. I gave my supervisor what I thought was a careful analysis of educational trends and perceptions. This meant concretely that I gave an account of people's perceptions of education based on our interviews with the surveyors and other actors in Uruzgan. But this was not what my supervisor wanted. She wanted numbers.

Doing Numbers

Many scholars examine numbers and they do so in diverse contexts. Some have investigated the cultural variations of numeracy (Crump, 1990) or have examined a broader ideal of quantification and objectivity (Porter, 1995; Daston and Galison, 2007), on problems of referentiality and accuracy (Poovey, 1998; Mitchell, 2002; MacKenzie, 1999), and on statistics (Asad, 1994; Hacking, 1990). Others have investigated cultures of audit and accountability (Power, 1997; Strathern, 2000; Anders, 2015), the work of rankings (Sauder and Espeland, 2009), and indicators under the sign of governmentality (Merry, 2011; Davis et al., 2012; Rosga and Satterthwaie, 2009; Shore and Wright, 2015). What all this work has in common is that it argues against the illusion that the world can be

neutrally represented and accessed by measurement. This article joins those who claim the world is heterogeneous and multiple. I add that one of the key technologies used for representing this world – number – is itself a multiple, taking a sense of instability up to the power of two.

Across the board, the way numbers are handled in the above-mentioned literature, is as stable and passive communicators of the world around them. Number is largely seen as a political technology that reduces complexity to make visible otherwise obscured social trends. Numbering or measuring can then be critiqued for the fact that it comes to replace relations of trust and it can subsequently turn evaluations into technical questions of measurement rather than explicit political judgment. Or, numbering can be critiqued for its claim to neutrality while it is all along invested with the values and life worlds of the individuals who employ them. Even if measuring is understood as generative of a host of subjectivities, cultures, understandings of probability or objectivity, redistributions of responsibility, rituals of verification or new expertise, numbers are taken for granted as exemplifications of arguments or as effects of some diffuse magic and charisma. Even if the authors just mentioned would agree that numbers are diverse and have effects in the world, the way they might actually dynamically participate in the valuing and ordering of our worlds as actors with complex properties and potentials, is nonetheless seldom explored and addressed.

What if we instead open up what goes on within numbers and numbering practices? This article intends to do just that by exploring the active and performative power of numbering. It relies on the work of scholars that do not take numbers as coherent or passive, drawing on the extensive exploration of number as inventive frontier (Guyer et al., 2010), of number's liveliness and embodied relationality (Verran, 2001, 2012, 2013), and of numbers as compositions that we live with and in (Day et al., 2014). To analyze numbers as active and lively, I take four steps.

First, numbers actively participate in the ordering of our worlds. Consider this example of a number's capacity to interpellate (Verran, 2001). I give someone a piece of writing with the number 8 inside a red circle on it. The recipient smiles. In this moment the writing is numbered, but this is not all. The handing over of the paper enacts the recipient as a student, me as a professor and the paper as a valued item that is transformative. In numbering practices people, technologies and objects participate in numbering and attune themselves to one another according to the numbering logic. Participation doesn't just happen through "knowing numbers" as valuing objects, but also through sensing who is part of the numbering context and through gesturing at new participants (Day et al., 2014). It is in this encounter that people and objects become related under the sign of number and that numbers come to matter.

Second, I use the concept of the interface as an analytic to ethnographically investigate the way numbers interact with their environment. To call what I do 'an ethnographic investigation' may raise the expectation that I do an ethnography of subjects, of people using numbers. Instead, I offer an ethnography of a number, as a technology, an entity, a tool, or an inscription. The interface is the analytic means by which I pursue the idea that numbers as entities have a form and a way of life that can be explored ethnographically, no less than the members of a group of humans can be said to have. Numbers' capacity to value and order the world – and this is no different with humans or other technologies – resides in its interface with others and other things.

Callon and Law's (2005) work on Cochoy's term qualculation is helpful to ethnographically grasp the moments in which numbers interface with their environments and transform. They argue that the notion of calculation is not an issue of quantification alone, but instead is a mix of quantification and qualification practices, calculation and judgment (Callon and Law, 2005). This practice of qualculation can be phased in three steps: the sorting out and detaching of items, manipulation of these items, and the extraction of a new entity. Each step towards quantification depends profoundly on qualitative judgment and draws in a host of specific skills, technologies and ambitions. While these steps offer an ethnographic orientation to the transitions involved in numbers' shifts between evoking uncertainty and certainty they shouldn't be read as a progressive series towards impassive abstraction. While Callon and Law helpfully point out what numbering

protocols might look like, they overlook number's particular contributions to it, reducing number to what people do with it.

Numbers have specific capacities, however, and these are activated in numbering encounters. This is the third analytical step that I take. Numbers have an internally complex multiplicity that is called upon in specific ways in particular situations. What kind of order numbers effect depends on the particular capacity that is animated in the encounter. Verran (2001, 2013, 2015) has proposed several epistemo-cultural properties of numbers. Numbers can, for example, orient towards the past or evoke futures. They can be representational truth claims or demand immediate action. Or they denote parts, wholes, quantities or series. These semiotic, temporal or generalizing modes that are called on in the encounter contribute to a particular organization of the elements of the encounter. Numbers that inspire immediate action will, for example, evoke a sentiment that propels us into the future rendering unthinkable questions about their accuracy or the way they have come together in calculations. The capacities of numbers that are animated in numbering practices therefore enable or disable particular choices, but also influence compatibilities with technologies, transportability, and affectivity. It is here where numbers make a difference, persuading towards certainty or inspiring doubt; enumerating environments beyond the referent; mobilizing certain people and resources rather than others; making particular worlds possible rather than others.

However – and this is the fourth step – this semiotic, temporal or generalizing multiplicity that makes up number still appears singular. Number's capacity to be singular and multiple at the same time depends on dynamic doings with hands, computers, papers and more. In these doings number emerges as singular while constantly being realized from a multiplicity of uncertain potentials. Number *is* the relation of tension, or, number *is* the interface, between singularity and multiplicity, between reference and iconicity, between specificity and generalizable extension, between agency and passiveness, between reality and analytical construct (see Verran, 2001). The notion of the interface in the way that I use it, both attends to the ways in which numbers relate to, bring into being and know the world around them, and at the same time it expresses the oscillation between evoking certainty and uncertainty about the accuracy, relevance, or presence of what it is that number knows.

In what follows I will investigate the coming into being of 6.15% as it emerged in three numbering practices: the cleaning of data collected by the surveyors in Uruzgan, the analysis of this data in the Kabul headquarters, and the presentation of the evaluation data in the report. This paper does not argue that it is in this linear sequence of research steps that truth is revealed by number either as a reality of education or as a reality of uneven power relations embedded in evaluation research. In other words, this paper is not concerned with the politics of representation that numbers may exemplify, nor with the accuracy and adequacy of the research protocol through which it has come into being. Rather, it wants to unsettle the stability and passiveness that keeps number unremarkable in analyses of the world around us. The following three stories present three distinct and separate numbering practices through which numbers come to act with three distinct sorts of capacities: i) the capacity to effect reference, ii) the capacity to constitute proportional comparison in terms of a population, and iii) the capacity to evoke doubt and certainty. An analysis of these capacities shows the ways in which numbering establishes girls as research entities, as parts of a population, and as a concern for the Afghan government and the international intervention. It therefore enables an understanding of the specific ways numbers relate to, bring into being and know education as a phenomenon in contemporary Uruzgan, while never completely succeeding at stabilizing the accuracy or relevance of the order and value number claims.

Reference

The donors want to know about the education of girls. My task is to now transform the Excel sheet data that was effectively "speechless" into numbers that have a voice (Harper, 2000: 24). Within the Excel sheet I look for the numbers of

girls going to school. The column that logs these counts lists more zeros in certain districts than in others. This raises a few questions for me. One explanation could be that most schools are boys' schools, and for those it makes sense that the entry for girl students is a zero. Another explanation could be the fact that many of these schools are closed. However, upon closer inspection of the workbook, many closed schools still list the numbers of students, services or classes. How can we explain this? Maybe a school that was closed because of Taliban threats is still secretly offering classes? Or maybe a school that was closed because it was still under construction had started teaching in already finished classrooms? Maybe the student count listed was the amount of students that would have attended if the school were open or the amount that had attended in the past?

The numbers in the Excel sheet had traversed a significant distance along a chain of reference – from local informant, to surveyor, to our Afghan project manager who had entered the data in the Excel workbook, to me, the data analyst – and would eventually continue on to the Dutch embassy and associated government officials in The Hague. The occasions for misunderstanding along this chain were multiple. As the information upon which this evaluation was based emerged from a context of frequently violent local tensions, a significant degree of linguistic or educational differences, and a style of keeping records that is not quantified, how did this affect the reliability of the numbers? Maybe the local informant had not been up to date about the latest educational developments in his district, or maybe the surveyor had not found the right informants to speak to. Both of them might perhaps have preferred the social status of knowing, even if this implied pretending, over the scientific ethos of accuracy.

Then there was our Afghan project manager who had made certain decisions in the process of assembling and translating the Pashtu data in one workbook. One issue he had to deal with were the unanswered questions of the paper questionnaires and the subsequent empty cells in the Excel workbook. Excel cannot easily perform its calculations when cells are empty and so our project manager had to fill them with data. It was not fully clear to what extent he had scrutinized the empty cells, investigated the value to be assigned to them, and entered the corresponding number, even if this meant a zero. He might have entered zeros in all the empty cells along the logic that the number zero corresponds most to the meaning of an empty cell. He could also have been meticulous about certain values that mattered to him and less concerned with respect to those that did not.

And then there was me. As a female Dutch PhD student in Anthropology, who was new to Afghanistan and hardly spoke Dari or Pashtu, what did I know? Being trained in critical theory made me cast doubt on anything claiming to be objective or factual. Furthermore, I had hardly any knowledge of or experience with evaluation research so on what did I base my assessment of the accuracy of the data? Did I have the cultural and linguistic sensitivity for an assessment like this? Were my misgivings even helpful? Or were my reservations preventing me from seeing the crux of the matter: that in order to establish the reliability of numbers, one needs to rely on the chain of reference and trust its transmissions?

The uncertainty with regards to the reference and accuracy of data is a familiar problem to many working with numbers and Excel. The specificities of the Afghan situation, with its problems of access due to security protocols and cultural and linguistic differences, makes this conundrum all the more visible. How to think about this uncertainty? How to reconcile that there may be nuances in the world that the surveyors have overlooked or nuances in the surveyors that have no references in the field (Latour, 2004; see also Lippert, 2018, with a sophisticated treatment of certainty/uncertainty in numbering practices)? In his article on soil sampling in the Amazon forest, Bruno Latour (1999) argues that the relation of reference does not naturally exist between word or number and thing but is established in a series of mediations ranging over the production process by which the reference, its accuracy and its transparency are produced. The Excel sheet is therefore not a mirror of what is happening out there in the educational field in Uruzgan: it requires a lot of work for the belief in its referencing capabilities to be possible.

How does the number interface with its environment here? Excel's technical requirements, as said before, require that evaluators make modifications in the numbers. Cells are filled, and language, both numerical and linguistic, is standardized. But there is other technology, too, that the numbers need to be compatible with. As the donors want our evaluation results presented on maps, Excel needs to work with cartographic software, and the GPS coordinates in the Excel workbook are the gateway into this Geographic Information System. In our case, however, once the coordinates and their educational attributes were entered into GIS some turned out to fall outside of the cartographic grid of Uruzgan into places as far off as Kazakhstan and Japan. These coordinates only verify themselves to a certain extent: if one of the first coordinates is off, the dot will end up outside of the boundaries of Uruzgan, but if one of the last coordinates is incorrectly copied from the device, the difference might only be a few hundred meters. A general check of all the coordinates was needed to ensure they would appear on the local map and, as such, count as part of the picture of Uruzgan's education.

Other adjustments were done in order to make our expectations from the field match the numbers in the Excel sheet. An example of this was a breakdown of the number of Uruzgani students. After an initial count, high school students outnumbered elementary students. This seemed highly unlikely for a place that international organizations knew for its steep illiteracy numbers and where parents relied on children as labor power. A check revealed that certain student counts had been entered twice, both for the school's main location and the school's annexes. Adjusting this did not correct the trend according to our expectations. In the final report, this mismatch was suggested as an error in the data collection and identified as a gap that called for further research.

In evaluation lingo number's interfacing with its environment is called data cleaning. It is a practice that calls on number's capacity to effect reference. It connects numbers to matter, through intermediary adjustments that follow the doubts that numbers raise either with regards to technological compatibility or to expectations of the field. As this account of the cleaning of the Excel workbook shows, it requires a lot of work to have a number make sense. They are calibrated internally, cohering expectations, demands and requirements of a network of technical and material routines and people with different tasks and skills. The effect of this internal tinkering is number's reference to something external; a value that makes sense within a larger context. However, as others in different contexts have shown (Poovey, 1998; MacKenzie, 1999; Mitchell, 2002 in the fields of respectively early-modern accounting, nuclear missile testing, and colonial cartography) the connection between referent and sign comes to be seen as naturally and accurately so and all the work that has gone into the process of calibration is seen as part of the process of extracting the story of the numbers rather than as part of making that story.

Let me emphasize this point. Making the story involves the transition from numbers as part of the reality of data collection to numbers ready to participate in analysis. Consider the problem of "nothing" (see Neyland (2018) for a parallel issue). Dealing with empty cells, "nothing" is turned into a problem of "nothing" into an account of "nothing" (the sign zero) as the solution to the problem of nothing. In other words, "nothing" – which is everything that escapes attention and problematization – becomes "nothing" – a manifestation of a problem – and gets the appropriate inscription of "nothing," the sign zero, which doubles as both the indication of the problem and the solution (see also Rotman (1987) on zero's participation in two logics). The empty cell was ambivalent and incompatible with technology. Internal calibration enables the filling of the cell and as its effect, there is now a referent, albeit a negative one, in the world, ready for proportioning in the world.

Proportionality

In order to produce numbers that indicate something, I have to apply arithmetic formulas that are embedded in the Excel program to selections of data. The Excel handbook that I consulted made it seem like this was simple. In fact, the single mouse-click that would reveal the patterned and

ordered world hidden behind the numbers would save me so much time, according to *The IT Girl's Guide to Becoming an Excel Diva*, a pink handbook keen on pitching Excel's compatibility with the life of a socialite (Babaian, 2008).

The mouse click is indeed simple, but it is not so obvious which data to click on if I want to make the number of girl students reflect "educational achievements." How do I deal with the fact that many families value a girl's education but prefer her to be home-schooled? How do freshly built but unused girls' schools in a safe district play into the story of educational development in Uruzgan? Should we offer a number to show disparities among girl students across Uruzgani districts? This would reflect, for instance, that where Hazara minorities live in the largely Pashtun south, the numbers of girls going to school are higher – as they are much more inclined than other tribal groups to send their girls to school. It is very well possible to ignore and conceal this disparity by producing a number for the province as a whole. It is precisely such baselines, expectations and moral understandings of what education or development should look like, that determine the parts and wholes we use in the work of proportioning.

This is curious work, though we tend to take it for granted. Calculating our way through the data we end up with "6.15% of Uruzgani girls go to school". 6.15% is a way of expressing a ratio of 6.15 to 100, which in turn is a simplification of the ratio of two quantities found in the field. Here my analysis follows Helen Verran's (2013) who picks apart a percentage in a similar fashion. The quantity that the numerator 6.15 represents is a simplification of the number of girls counted in the field all added together. By itself this number indicates nothing without the help of another number, the denominator. This denominator is not simply another absolute number but a whole — the numerical equivalent of which is 100. What this denominator represents is the total number of school-aged girls in Uruzgan. While the numerator was derived from the total of the counting efforts of the surveyor, as we saw before, the denominator has a different origin. An exact number is unavailable: a precise population census is lacking.

Some educated guessing yields a quantity of Uruzgani school-aged girls. A population pyramid of Afghanistan drawn up by another international organization estimates that 70% of the population is 18 years or younger. Health data for Afghanistan indicate that about 20% of all Afghans are under the age of 5. We take these numbers to hold for Uruzgan as well, which means that 50% of the Uruzganis can be considered of school age, of whom 50% must be girls (TLO, 2010: 20). This allows us to calculate a denominator of which the numerator becomes a part.

So, there are significant differences between the denominator and the numerator. They differ not only in terms of their graphics and their location above or below the fractal line, but also in terms of "the institutional and literary routines" (Verran, 2013) from which they emerge. The girls to whom the two numbers refer are different as well. The surveyors with their questionnaires and pencils who write down the counts that some school's headmaster or local education minister reports to them, know the numbers differently than I do: whereas I sit behind my computer, surfing for previous approximations by other organizations who may have been committed to knowing education differently themselves (on knowing education differently, see also Gorur, 2018). I use the estimates that I find to compute another number that by now no longer comes with traces of counting. Whereas I have been imbued with an authority of knowing and reading the numbers based on my educational background and my association with the internationals, the surveyor knows and reads numbers in his capacity as former employee of the Department of Education in Uruzgan. And whereas surveyors may have research protocols in mind (or food on the table or social prestige or all three) I have deadlines to mind, my own reputation within my professional environment, or the position of my research organization in a larger network of competition for assignments from donors (if the picture I am painting may seem stereotypical, I would like to stick with it for the sake of the argument). Moreover, whereas I construct an imagined quantity of girls as part of a population of students that are a development target, the surveyor might count girl students as a means to receive more valuable development, such as infrastructural projects, in return.

The individual-to-society scale is the master narrative of the 6.15%. This narrative determines how number interfaces with its environment, which parts to identify (girls going to school) and how these parts relate (arithmetically) to a larger whole (a population of school-aged girls). This interfacing between parts and wholes makes number well suited to do political work, calling to work its capacity to constitute a proportional relation between numbers identifying individuals and those identifying society. Following Guyer (2014), I'd argue that the stability of the percentage form is an achievement of form, turning the focus on the possibility of de-/increase of the proportion rather than on the constituents themselves or the mathematics of their relation. Moreover, with the mathematics of proportion the moral sense of due ratio and fairness slips in, further substantiating the individual-to-society relation, concepts such as the micro and the macro, and a version of the social that has become so well-established that it seems natural. In John Law's terms, it is a romantic version of the collective that imagines the whole as coherent and to be discovered "in a manner that is single, centered, explicit, homogeneous, and abstract" (Law, 2009: 249). Girls are stripped down to countable educational characteristics that can be aggregated to produce a whole in which these characteristics are proportionately distributed.

This is the business of statistics and its possibilities and limitations have been discussed by many (see for example Asad, 1994; Hacking, 1990). As Corsín Jiménez calls it, in a reflection on the measurement of well-being, a focus on the units eclipses the relations between and within them: "We come up with a number but lose track of the social; we end up focusing on the units that are aggregated and not on the mathematics of aggregation" (Corsín Jiménez, 2008: 182). Yet, while certain complexities and nuances of society disappear behind the fiction of its measurement, another kind of society emerges in these practices, and this enactment swiftly shifts between the way society has been made compatible with spread sheet practices to a project with value for the future, an invitation to further investment. I will address this in the next section.

The different trajectories of the numerator and denominator discussed above point to the politics of the number. There are other scales and relations between parts and wholes at work in the name of Uruzgan's education: girl students as part of a girl student population, student populations as part of professional ambitions, food on the table as part of girl students, deadlines as part of student populations. Computing and aggregating these parts and wholes differently, might, in turn, yield different and more poetic versions of the social (see Ballestero (2014) for an appreciation of percentage's capacity to expand meaning that exceeds mechanical or informational purposes). If anything, they complicate thinking about scales as the relation between parts and wholes, not along an imagined vertical axis from small and simplified individuals to big and complex societies, but along different logics of connection and distribution.

Evoking certainty and doubt

So now we've arrived at the 6.15%. A few certainties have crystallized (see also Lippert, 2018): we have established that there are girl students who go to school, who can be counted and taken as a proportion of society and which can be represented in a percentage. The 6.15% refers to a number of girls going to school in relation to a population of school-aged girls. We still don't know, however, how to think about this number: whether it is an achievement or a disappointment. To better know the value of the number, we need to compare the 6.15% to an external standard.

In the final report – *The Dutch engagement in Uruzgan: 2006–2010* – 6.15% makes its first appearance in the well and often only read executive summary at the beginning of the report. Here the percentage is singled out as important and is only listed among three other important educational figures related to the construction of buildings, operational status and location of instruction. Given the vast number of indicators and other figures that the analysis of the educational data yielded, the fact that 6.15% made it into the ex-sum means something:

> In Uruzgan province it is estimated that 20% of all school-aged children attend school, a figure which is significantly lower than the national average of 50%. The percentage of girls enrolled in Uruzgan's schools is even lower and estimated at about 6.15%. (TLO, 2010: vii)

Now we know that the 6.15% is actually "significantly" low. This is not in comparison to a temporal baseline: 6.15% could very well appear as an improvement against percentages of girls going to school in Uruzgan in previous years. It is, instead and probably unnoticed by many, a comparison of a provincial percentage against the national percentage. This liberal interfacing of 6.15% with the comparative context of the national percentage rather than with change over time might be an epistemic failure in evaluative terms, yet it isn't about epistemic accuracy here anymore.

The number performs differently once it is up for presentation. For one, it propels us into the future (see Verran, 2012). Whereas the numerator in the previous section reports a past reality of counting and registration without any value beyond that, its subsequent contrast to the denominator and the national percentage turns the 6.15% into an "iconic" number: value and category have become the same and the referential accuracy is not at stake anymore. Even while its accuracy is admittedly flawed, we evaluators think it is accurate enough and should be published in order to make a particular case. The number is no longer a re-presentation, but evokes an order of things, a world where education is an aspiration, maybe even an obligation for the citizens of a democratic state. These citizens are to be equal: girls should not be discriminated against and have as much right and opportunity to go to school as boys, to educate themselves and grow into adolescents with perspective and opportunities. But the 6.15% does more than call up this world. It also mobilizes for wholeness and fullness, and inspires to aim for the 100%. Hence, it is no longer a registration of girl students but has become a number ready to be employed in the business of articulating futures and generating policy. 6.15% could justify Dutch taxpayers' money spent on education, and ongoing investment in Uruzgan against the grain of the Dutch public's rising skepticism regarding their involvement in international development.

I could end my account of the life of the 6.15% here. I would have shown how data presentation calls on number's capacity to imagine a world and inspire action towards it. I would have framed the transformation of the numbers from the Excel sheet to the report as one from weak numbers to hard facts. The 6.15%, however, appears once more in the body of the report. And this time the percentage does not evoke quite the same sentiment.

The "Achievements in Education" section (TLO, 2010: 16-22) starts with an acknowledgment of the limitations of the data collected before 2010, complicating "an accurate comparison" with the data collected in 2010. After this, the reader is pulled through a maelstrom of numbers: there is text with numbers of school buildings broken up per district, per gender of students, and per operational status. Then the number of school buildings is once again broken down, this time in bullet-point style, per category of educational level. Then there is a new breakdown in table format: within the first column is a comparison of 2006 and 2010 figures; in the second column are arrows, blue and up for progress, green and sideways for stagnation; in the third column is another detailed breakdown of those school buildings that were added since 2006 (where what was already present and what is new is unclear); and in the last column are percentages and absolute numbers of school facilities that are not official school buildings, broken down per district and type of facility. Then follows a narrative in which another variable is introduced — that of ethnic or tribal demography — one which is suggested to bear relation to the distribution of schools. Along with this is some information about the work of NGOs still going on, narrative text on student enrolment in absolute numbers (broken down per regular and occasional attendance and per educational level), girl attendance mentioned in brackets, a table with absolute numbers of children going to school regularly and occasionally, and then, there it is, the 6.15% measured against the national and provincial average of school attendance, and broken down per district.

I will not take you through similarly complicated sections in which more student and teacher figures are broken down. The issue is not to point

to the evaluators' bad writing. To the contrary. The report is carefully put together and as writers we made sure to include all the trends we discovered and all imaginable explanations. What I want to point to is the shift between numbers as value, as development trend and numbers as valueless registrations that can be mobilized to represent a developmental trend. These two versions of the number can both jeopardize and strengthen each other's claims. Let me explain.

In my contributions to the writing of the report, I constantly felt compelled to condense the text. Rather than adding more possible numerical distributions of characteristics of Uruzgan's state of education, I wanted to reduce the amount. I thought less numbers would yield more power to our claims. Instead more numbers would reveal how easy they (along with figures and percentages) can be made and would ultimately take away from what numbers told us. This seemed to me exactly what the body of the report did. The different contrasts, ways of breaking down, partial explanations, disclaimers and explicit mention of the absence of reliable numbers only emphasized that there are ever so many alternative ways of proportioning, possible standards or benchmarks, explanations, and ways of relying on numbers.

It may seem as if the last appearance of the 6.15% in the body of the report, brings the number full circle, throwing it back into the chaos of randomness. And it may seem as if the confidence that the 6.15% exudes in the executive summary is blown away by the numerical whirlwind later on in the body of the report. But while in other genres an exposé like this would raise eyebrows and provoke questions of relevance, accuracy, or style, this whirlwind does not evoke uncertainty and doubt for my fellow evaluators or the donors. What looks like a collection of data without a vision, is in fact a logic of filling in, completion and completeness, of summing up (cf Riles, 2000). This desire for always more data trumps a logic of building arguments where data is processed into words, sentences, paragraphs, arguments altogether. In the body of the report, one plus one is not the new figure of two; one plus one is instead a plurality of ones. The more units of one we can add to the story, the more solid it becomes. So, rather than jeopardizing the claims of the executive summary, the logic of summing up numbers and claims about numbers grounds these claims. Number interfaces here with readers. Depending on these readers, the number can be the order and value it claims and inspire towards action accordingly or the number can evoke unmoored chaos and inspire distrust and disconnection.

Conclusion

In this article, I have told three stories of numbers between counting and accounting. In these stories numbers actively engaged with their environments—their social, cultural and political milieu—with differing effects. Let me revisit here numbers' agency, their ways of interfacing and capacities for order and value, along with the effects of these encounters.

Numbers are active participants in the ordering and valuing of our worlds in different ways. Most importantly, numbers can inspire doubt as to what something means, demand action for clarification and, subsequently, exude confidence. Moreover, numbers indicate the numbering practitioner, their audience and their referent. They can raise questions about the quality of these relations: is a number accurate, does it relate to the right audience, and is the practitioner trustworthy? Numbers can also enable or disable the working of software or question expectations about Afghanistan. And they can evoke worlds, orient towards the future, or bring the past to mind.

How do numbers interface with their environment in this case? They are embedded in a methodological protocol that stipulates a sequence of actions to be applied to them. This protocol dictates that the number travels from paper questionnaires to an Excel workbook, from data cleaning to analysis, and from analysis to publication in a report. This sequence requires the number to interface with a host of technologies such as Excel and GPS. In addition, they interface with a mathematic of the social and with the expectations of what reality looks like in Afghanistan. Numbers interface with text, from Pashtu to English, according to a logic of composition that is particular to executive summaries and evaluation writing. But numbers also interface with readers.

In each of these moments in the numbering interfaces described in this article there is an initial uncertainty as to what the numbers mean. What do all the zeros in the Excel sheet mean? Which numbers are supposed to make up the parts and the wholes of the proportions? Is 6.15% a sign of the success of the Dutch intervention? These uncertainties require responses and set in motion a series of actions, of manipulations of sorts, to resolve the questions the numbers raise.

In the process of interfacing one of number's many capacities is activated. Number's referential capacity enables it to evoke Uruzgan's state of education as a reality that is out there, available for measuring. In another instance numbers' capacity for proportional comparison enables numbers to participate in a mathematics of the social and to generalize in terms of populations. Or, numbers orient to the past of their coming into being or inspire to action for their cause. Importantly, numbers are caught in an oscillation between evoking referential doubt and evoking confidence or action (until they don't anymore and someone or something throws the numbers back into a pool of questions and uncertainty, demanding clarification, and so on). Rather than weakening the power of numbers, it is in this contradictory oscillation, *as* interface, that numbers are generative.

What are numbers generative of in this case, then? They participate in the making of Uruzgan's education. They make possible an understanding of Uruzgan's education as one that is known through numbers. Uruzgan's education is what can be quantified and listed in Excel sheets. Its contours emerge in the list of characteristics of schools and schooling. Its trends and tendencies are revealed through the application of mathematical formulas. And encouragements for social change gain power when they appear in the form of indicators and percentages. These are matters of governance, in the sense that numbers and numbering practices make entities, contexts, mobilize sentiments and suggest action. As this article has shown: numbers help to transform "nothing" (a potential without attention) into girls as a data category, into girls as a group of individuals that are part of population, with a particular distribution of characteristics, into an urgent concern for the international community.

My analysis foregrounds numbers as relational entities, that numbers have the capacity to do things and that what numbers do is situated. The notion of the interface helped me to bring out number's relationality. Yet, the interface isn't an external affair only. It isn't about what number can do and effect through its relations. The interface *is* the number, as an oscillation between doubt and certainty, towards stability and chaos.

Evaluation may easily be understood as a difference between a before and after picture. New figures are contrasted with baseline numbers and the difference is to be explained by the logic of development. If we stop thinking about numbers as symbolic communicators of the world but start seeing them as entities with specific capacities for generalization, for guiding our attention towards the past or action in the future, for oscillating between representing and being value and order, the analytical functions of numbers change. Numbering, in its wake of evaluation, has manifested itself as a contradictory coproduction between people, inscriptions, technologies and more, always trying to push to the background the traces of this co-constitution as these traces are deemed irrelevant. Bringing the practice of numbering and the capacities of numbers to the fore provides an opportunity to not only critically assess them as end products but to carefully assess the worlds that emerge alongside numbering practices and the ways that processes of governance work with and through numbers.

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Escaping Numbers? Intimate Accounting, Informed Publics and the Uncertain Assemblages of Authority and Non-Authority

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Abstract

Recent decades have seen a significant rise in the use of numeric evidence in education policy and governance. Using the case of the Education Revolution in Australia, this paper explores the processes by which both 'distant accounting' and 'intimate accounting' were made possible by new national assessments and a public website which published comparative information about schools' performance on these assessments. Building on concepts proposed by Kristin Asdal (2011) on intimate actions in accounting, the paper elaborates how Australian regulating authorities created new intimacies by compelling schools to reveal details they might have preferred to keep private. Parents, and the public in general, came to be seen as deserving of such intimate information, and as capable of using such information appropriately. The resulting 'informed publics' then played a significant role in the productions of authority and non-authority. Various efforts unfolded to challenge the authority of numbers and to escape being governed by them, by subverting the efforts of quantification and refusing the numbers that were produced. Tracing the story of the Education Revolution affords an opportunity to elaborate the processes of 'accounting intimacy' suggested by Asdal (2011) and to examine the relationship between 'the production of non-authority' that she described, the production of 'non-calculation' suggested by Callon and Law (2005), and the concept of 'informed publics' conceptualised by Callon et al. (2009). The paper proposes that 'distant' and 'intimate' forms of accounting are not mutually exclusive, but can operate simultaneously and even reinforce each other, and it describes how this was achieved in the Education Revolution.

Keywords: sociology of numbers, education policy, accountability, informed publics, escaping numbers

Introduction

While quantification and measurement have long been features of social policy and governance, there has been a steep rise both in the generation of numeric data and in the significance accorded to numbers in recent years (Miller, 2005; Rose, 1991). In education, the deployment of standardised, large-scale assessments at national, regional and international levels has been on the rise since the 1990s (Espeland and Stevens, 2008; Lingard et al., 2013; Simola et al., 2011; Strathern, 2000;

Steiner-Khamsi, 2015). This increase in large-scale assessments is in part due to developments in psychometric and statistical sciences, which have generated global indicators for a variety of educational phenomena (Gorur, 2015a), and in part it is an effect of the rise of 'evidence based policy' and more generally the expansion of neoliberal forms of governance (Gorur 2011a, 2011b; Rose, 1991; Strathern, 2003). As marketisation and deregulation have gained prominence over the last few decades, the traditional roles of 'government' – regulation and control based on a set of political and moral philosophies – have come to be rethought and replaced in many ways by the practices of 'governance' associated with orchestration and management. 'Ideology' came to be replaced with 'evidence,' most often numeric, or at least produced by independent, distant, disinterested, external, expert consultants assumed to be neutral (Porter, 1994).

One of the first countries to popularise the term 'evidence based policy' was the UK. The then Prime Minister Tony Blair summed up this new form of governance in his manifesto with stark clarity:

> New Labour is a party of ideas and ideals but not of outdated ideology. What counts is what works. The objectives are radical. The means will be modern. This is our contract with the people (Politicaresources.net, 1997)

"What counts is what works" in this form of 'New Public Management' (NPM). The quest for 'what works' has set in motion a particular type of accounting machinery. Once 'what works' is identified, the narrative goes, governments need only operate at arm's length, steering from a distance (Rizvi and Lingard, 2010). Citizens, corporations, schools and other entities can also be responsibalised to do 'what works' since 'what works' can be translated into targets and key performance indicators (KPIs). Transparency and accountability practices would facilitate the monitoring of institutions and organisations. In the marketised, neoliberal economy, competition and the emphasis on consumer choice and privatisation would, it was believed, encourage individuals and organisations to perform at their best (Gorur, 2013). Otherwise, an informed and empowered consumer base would vote with its feet, forcing school closures or amalgamations (Thomson, 2002).

As these practices of quantification and the audit culture (Power, 1997) in education have expanded, so has their critique. One set of critiques has come from statisticians and psychometricians concerned with the accuracy of numbers and the practices of numbering, such as the models, theories and techniques used and the validity of constructs, assumptions and calculations. Another set has come from policy sociologists concerned with the ways in which these numbers are being taken up, used or misused in policy and politics (Gorur, 2015b). Sociologists of education have worried about the effects of these practices on students, families, teachers and schools. There has been great concern for issues of equity and social justice on the part of many researchers in education – particularly since inequities appear to keep rising despite efforts to redress them.

In this paper, I add to these critiques of numbers in education and problematize the power conferred on numbers in current studies of education policy. Focusing on the lively empirical site of Australia's education policy, I examine the imbroglio of politics, numbers, competing interests, changing relations and new instruments of measurement and monitoring in this age of transparency and accountability. The analysis brings together and examines the relationship between three different concepts related to the productions of authority – Asdal's (2011) notion of the production of *non-authority*, wherein the 'centre' or the 'office' actively seeks to devolve or decentralise authority through practices of 'accounting intimacy'; Callon's (2009) notion of *informed publics* in which previously distant actors are drawn into new relations with 'settled' accounts and summary calculations, resulting in the rearticulation of such accounts as controversies; and the notion of *non-calculation* proposed by Callon and Law (2005), which considers the conditions under which non-calculability may be achieved (or, in other words, numbers can be escaped). I explore how productions of authority and non-authority, and of calculation and non-calculation, are held together in the Education Revolution. Based on these explorations, I identify two new strategies that help in the production of non-calculation: subversion and refusal.

The uncertain assemblages of authority and non-authority

STS scholars have described the processes by which bureaucracies and administrative offices become centres of calculation, enabling them to exert influence on distant others (Latour, 1987). In these processes, synoptic apparatuses bring abstracted, standardised versions of distant objects of regulation into a central bureau where they can be tabulated, manipulated and ordered in ways that render the objects amenable to control (Scott, 1998; Porter 1995). The translation of objects into their stylized versions enables their reckoning for the purposes of the state.

If we regard the processes of gaining a synoptic view, abstraction, creating new facts useful to the state, and regulation from a distant centre of calculation as a detached and aloof type of accounting practice (or 'distant accounting'), Asdal (2011) has provided a description of another kind of governance – a more intimate practice which she calls 'accounting intimacy'. Asdal's (2011) observations about accounting intimacy arise from her studies of the regulation of emissions of aluminium factories in post-war Norway. Here, regulation and control were not exercised 'at a distance', but by the pollution control agency penetrating individual factories and by recreating the factory within the office of pollution control. This was done through a system of providing concessions to each individual factory, giving each factory, in essence, an individualised 'licence to pollute'. In this practice of regulation, there was a reversal of movement – instead of factories being translated into numbers and taken *away* to the centre, pollution numbers became vehicles through which the centre was inserted *into* individual factories. The centre thus became glued intimately to the factory site. In this way, a particular regime of accounting – an intimate form of accounting – replaced the practices of distant accounting and rearranged relations and produced new intimacies between the factory and the office of pollution control.

However, neither aloof steering at a distance nor intimate regulation is guaranteed success. Both calculation and governance are uncertain assemblages that require the cooperation and enrolment of a range of actors – cooperation that cannot be taken for granted (Callon 1986). Like the fishermen and the scallops of Saint-Brieuc, irrespective of regulators' 'will to power', authority may fail to be produced (Asdal, 2011), or it may only be partially accomplished. How and with whom actors might align themselves, and how these changed relations might impact the production of authority or non-authority, is difficult to predict.

How is non-authority produced? If 'authority' for administration and governance is based on the authority of numbers and calculations, then non-authority is also linked with non-calculation – or, as Callon and Law (2005) would have it, non-qualculation. Here, the use of Cochoy's (2002) neologism 'qualculation' is designed to draw attention to the particularity and the constructed nature of the spatio-temporal frames within which particular calculations become feasible. Callon and Law (2005) assert that both 'qualculability' and 'non-qualculability' are achievements that require effort. To create non-qualculability, they propose two strategies – that of rarefaction, in which the resources required for qualculation are withdrawn, and proliferation, in which qualculations are multiplied such that they do not remain stable – a single summation becomes difficult. The importance of a single number (or in the case of Asdal (2011), a single number series representing the declining levels of pollution) in maintaining authority and enabling administration can also be linked to Latour's (1987) 'immutable mobiles' – as numbers circulate, they require some stability to enable both calculation and authority.

Australia's Education Revolution provides a lively case study through which to examine and elaborate how the processes of steering at a distance *and* the more intimate forms of accounting are operationalised in tandem. I use the case study to elaborate Asdal's (2011) concept of 'intimate action' or 'accounting intimacy' and study the empirical ways in which various forms of intimacy are generated by new calculations and new forms of governance. I describe how these processes rearranged relations between actors, creating new intimacies and interesting and enrolling different and unexpected actors. I take a liberty here with the term 'accounting intimacy' and speak instead of 'intimate accounting,' prefer-

ring to use 'intimate' as an adjective, as a descriptor for a particular form of accounting – so as to contrast it with the distant forms of accounting evoked and enabled by centres of calculation.

In tracing the competing discourses and the challenges to authority as the Education Revolution unfolded, I link Asdal's concept of the *production of non-authority* to Callon et al's *informed publics* (Callon et al, 2009; Gorur and Koyama, 2013). As the government simplified complex calculations to make them available to the public, the public used these accessible numbers to challenge their accuracy and validity. Whereas the calculations were developed in a bid to eliminate emotion and 'irrational thinking' and to develop rational and 'evidence-based' machinery for governing, the newly mobilised informed publics managed to drag emotions and other 'irrational' elements back into the conversation. Calculations proliferated and became mutable 'matters of concern'. This took away some of their authority and created some conditions to escape the numbers. However, the twin strategies of distant and intimate accounting working together allowed the federal government to maintain the qualculative and administrative infrastructure, albeit as a leaking edifice in which at least some actors were able to subvert or refuse the numbers.

The empirical material for this study comes from policy documents; press releases from the education ministry; and from publicly available websites and accounts in the popular media.

Australia's education revolution

In 2008, Australia's Labor government ushered in a suite of 'evidence based' education reforms under the banner of the Education Revolution, heralding a heavy investment in new calculative practices. In Australia, education falls within the purview of state governments, and not the federal government. Before the Education Revolution, each state and territory had its own curriculum, examinations and assessments. The federal government's Education Revolution ushered in *national* calculations so that the whole nation could be judged against the same benchmarks.

Significant in the new reforms were new forms of responsibilisation of states and territories. Outcome calculations and comparisons were expected to serve as technologies of transparency and accountability, motivating states to achieve the targets set by the federal government:

> The Australian Government is moving away from the overly prescriptive approach of the past over how the States and Territories should deliver services. Accountability for performance under the new Commonwealth-State agreements will instead be achieved through *significantly improved public reporting*, focussing on key outcomes to be achieved by Australia's schooling system. (Commonwealth of Australia, 2008b: 33. my emphasis)

The most significant of the transparency and accountability measures were:

- The introduction of a nation-wide standardised assessment, the National Assessment Program – Literacy and Numeracy (NAPLAN)
- The development of the Index of Community Socio Economic Advantage (ICSEA) that enabled 'like-school' comparisons (i.e., comparisons of each school with 60 other schools with 'similar' populations); and
- The development of the 'My School' website – open to the public – on which each school was required to present a range of information about itself, including its performance on NAPLAN, which was presented both in absolute scores and as comparisons with other 'like' schools.

The reforms were championed by the then Minister for Education, Julia Gillard, through press releases, media interviews and her blog. Each step also met with rigorous opposition by various groups. The value of the tests was disputed, as were the calculations of the ICSEA Index. Ultimately, some changes were made to the calculations and to the information made publicly available. Thus numbers were done, challenged and redone in the Education Revolution. However, efforts to escape the calculus of NAPLAN and My School have not been successful – they have become well entrenched in the Australian education policy landscape.

Intimate accounting in the education revolution

Transparency and accountability were placed at the centre of the Education Revolution. Through a new national data and reporting framework, the government proposed to acquire a range of information about each school and become intimately familiar with them. It would also disclose that information to the public so that "parents and community members will be able to compare schools in the local community and their own school with schools with similar student populations around the country", as Julia Gillard explained in a speech (Commonwealth of Australia, 2008a). She added that her department's survey had found that 96.9 percent of parents agreed that it was important for them to have information about such things as the state of a school's buildings and infrastructure, its performance on national testing, and the qualifications and experience of the school's principal and teachers. Insisting that parents were "hungry for information", Gillard said that a range of new information needed "to be at our fingertips and at the fingertips of parents and teachers …".

The revelation of intimate details of schools to the government and to the public was seen as a necessary step towards transparency, and transparency itself, however controversial and keenly contested, was argued as necessary for improvement:

> Yes, I think we're going to have an argument about transparency, but … I've made it perfectly clear that we will want this information, we want parents to have it, we want the community to have it, and … we want it so that when we find where disadvantage lies we can make a difference to fixing it. (Julia Gillard, in a radio interview; Sales, 2008)

Here transparency itself comes to be presented as a rather violent form of forced intimacy. Despite the "argument" that ensued, the first round of NAPLAN was conducted in 2008, and in 2010, the My School website went live, carrying a range of data about every Australian school.

As with Asdal's (2011) factory, the numbers produced in this activity were tailored and individualised. This was not about knowing at arm's length, as with the abstracted numbers used in steering at a distance. These measures were about knowing each school intimately. But there was nothing 'private' about this intimacy – schools would be required to provide intimate details about themselves *publicly*. On the My School website, a host of details are provided on each of Australia's nearly 10,000 schools.

Figure 1 shows the NAPLAN results of a well-known private school in Melbourne displayed on the My School website. The menu on the left displays links to information about the school's finances, student attendance, and five different views of their NAPLAN results. Parents can see the school's NAPLAN performance in Years (Grades) 3, 5, 7 and 9 in a colour-coded comparative format, with the pale and dark green bands reflecting "above average" and "substantially above average"; white showing "close to average" and pale and darker red showing "below" and "substantially below" average. These data can be accessed for each year of testing as graphs, bands, and against "similar schools". Parents can see "student gain" – the change in performance between one NAPLAN test and the next.

This contrasts with the same school's own website which is not constrained by My School regulations (Figure 2). Here, attention is drawn to the opportunities and the care offered by the school. The opportunities include the possibility for students to make choices "unhampered by stereotypes". The valuing of diversity is signalled in the "many tribes" that children can find in the school. "The MLC Difference" on this website is not based on its relative performance on NAPLAN, but its emphasis on its curriculum, the co-curricular opportunities, the school's campus and facilities, as well as its "results" – not much is said about NAPLAN. Parents gain access to information on My School that the school might not otherwise not have revealed, or at least would not have not highlighted to parents (see also Gorur, 2015c; Gorur and Koyama, 2013).

Did the new calculations – NAPLAN assessments, the ICSEA index, the like-school comparisons, the other numbers from the My School website – help the government and the parents to know each school more intimately? Gillard certainly thought so. The day before the My

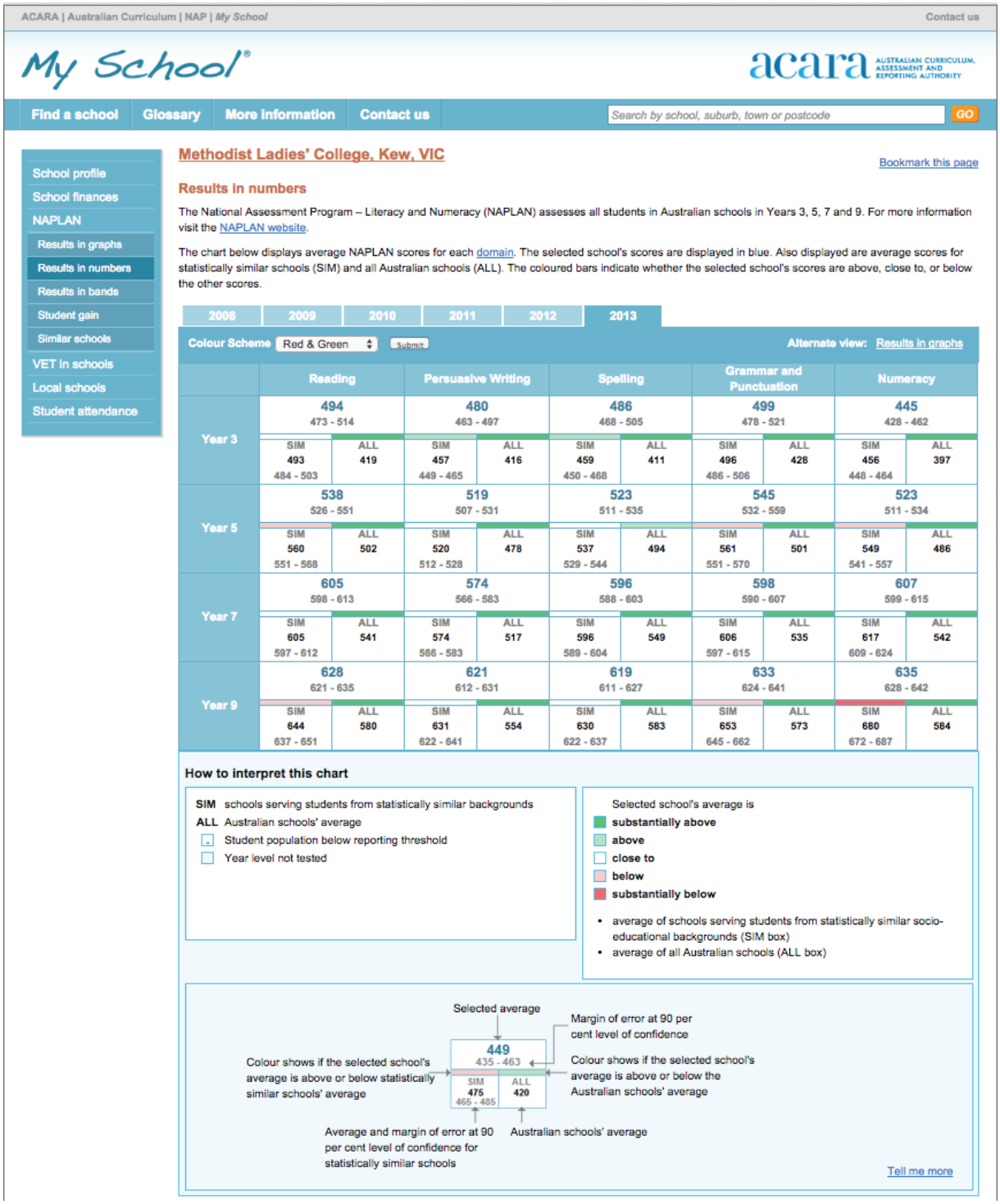

Figure 1. Screenshot of a page from the My School website ACARA (2018).

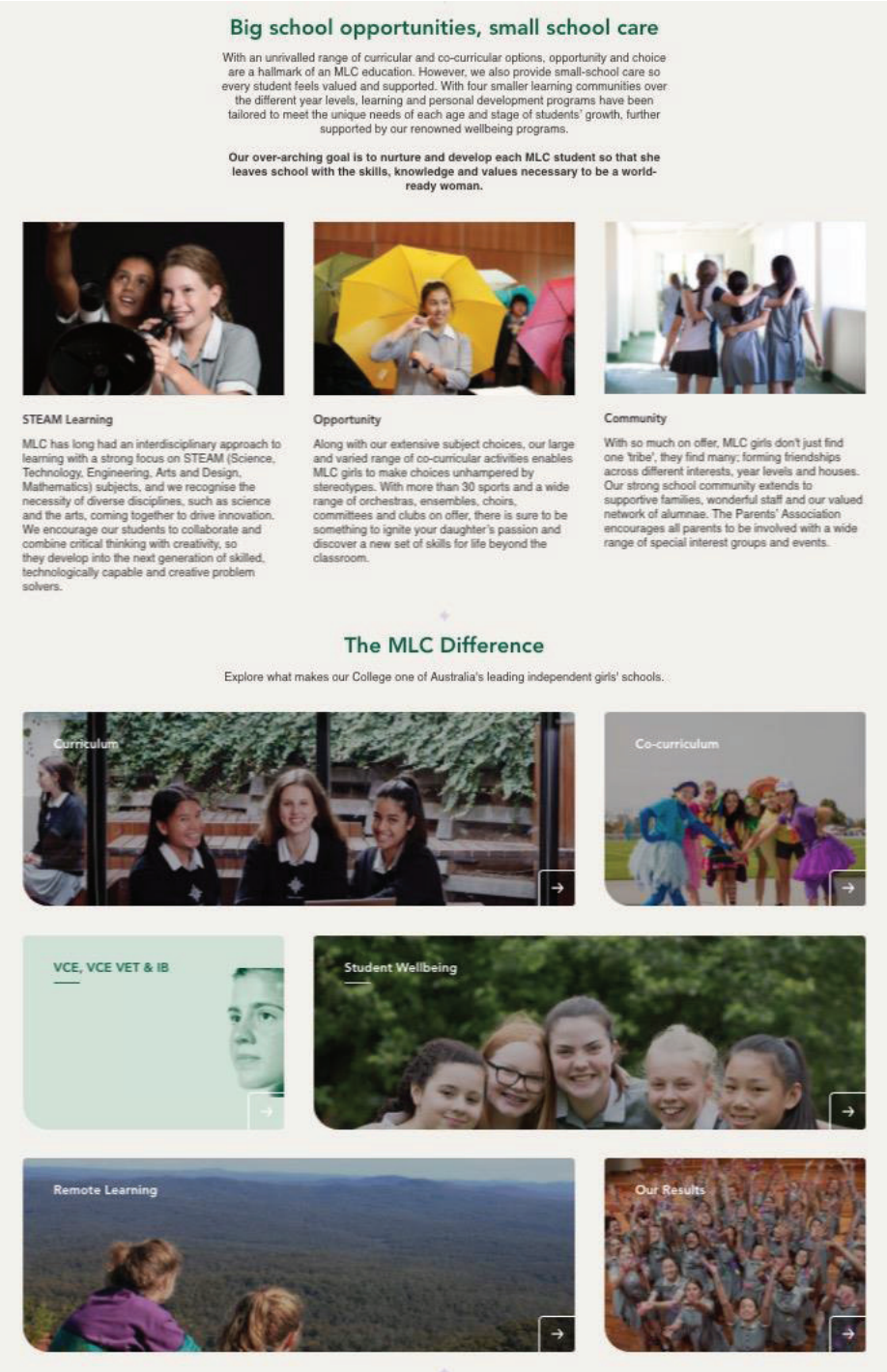

Figure 2. Screenshot, Methodist Ladies College website. Methodist Ladies College (2018)

School website went live, carrying the like-school comparisons to the public for the first time, she wrote on her blog "For the first time, parents will be able to see exactly how their child's school is doing".

The publication of like-school comparisons left schools feeling exposed and vulnerable. The regulatory power of the centre penetrated the most intimate spaces of schools, right down to resources and funding and student performance. At the same time, these numbers also spilled into other intimate spaces, as Gillard noted:

> Everywhere I have been since January 28th, people have told me stories about the conversations that *My School* has sparked. Conversations in workplaces and kitchens. Conversations between parents and school principals. Conversations between teachers in staff rooms. Conversations between parents and their children. (Commonwealth of Australia, 2010a)

The numbers in the Education Revolution thus began to mingle with people in many more places, mediating relations between various actors.

The Education Revolution's calculative practices produced an 'imagined community' for which these numbers were relevant. As Asdal (2011) explains, an 'imagined community' is not a *non-existent* one, but one that is brought together in and through the relational processes of calculation. First, there is the case of 'like schools' – schools that were deemed to be 'statistical neighbours', because the communities in which they were located had socio-economic profiles that were calculated to be similar. Prior to the Education Revolution, even the most competitive private schools in Australia had only to compare favourably with other nearby schools, with whom they might have competed for students. But with the like-school comparisons published on My School, a Melbourne School might find itself compared with schools hundreds of kilometres away, in Perth or Brisbane or Darwin, on the basis of the demographic profile of their student body. Distant schools were pitted against each other on the single feature of their NAPLAN results. Even if it is unlikely that parents would move to a different state just to enrol their child in a 'better performing' school, these distant schools had an impact on a school's rankings, and this in turn had the potential to impact how a school might invest its resources, prioritise its efforts or be affected by parent decisions.

Another 'imagined community' was that of parents, who were cast in the role of those who needed and deserved the numbers. They were presented as having the capacity, responsibility and the right to understand and use the numbers sensibly and to hold schools accountable. The government's stance is exemplified in this excerpt form a 2010 Media Release from Gillard, titled "My School to provide unprecedented school performance data":

> Parents will get unique access to data which tracks the progress of students in Australian schools with the launch of the new-look My School website…. This will provide unprecedented insight for parents and carers on the impact of teaching and learning across Australia's schools. The enhanced version of My School will also include financial information on schools. It will be the first time information on the resources available to schools will be publically available. ... Anyone will be able to follow a cohort of students as they move through school levels to see what progress they have made over the last two years. (Commonwealth of Australia, 2010b)

This 'right to information' on My School enacted a division into being – with the government and an imagined community of parents on the one side, eager to get to the bottom of what was happening at each school, wanting to track the progress of each cohort of students, and determined to have the numbers; and on the other side the schools, trying to protect their privacy from the prying eyes of regulators and parents.

At the same time, by claiming to provide more information than was ever before available to parents about their child's school, the government dismissed parents' personal and subjective understandings of schools, suggesting that the Education Revolution's dispassionate numbers were more authoritative.

The Education Revolution's numbers thus brought schools, parents and the government into new sets of relations. These relations were held together and mediated by NAPLAN and My School, which were devised as obligatory

passage points for schools. The intimate forms of accounting through which the centre inserted itself into each school thus begat a number of new intimacies.

Transparency, steering at a distance and informed publics

The new practices of intimate accounting did not replace distant forms of accounting. As with Asdal's (2011) case, the insertion of authority into each school via the numbers of the Education Revolution saw a replication of the 'office' (the federal government) at each site, as NAPLAN and My School became more and more firmly entrenched, and began to affect schooling practices more and more. But equally, every school site also travelled in stylised forms to the new centre – the My School website. This material-semiotic device, the My School website, mediated relations between the government, schools and parents in very specific ways and enhanced the authority of the centre.

A hallmark of governance is *public* accountability and community engagement with numbers and institutional accountability. Transparency and accountability are achieved through making widely available information that was previously centrally held (Power, 1997). The Education Revolution exemplified this desire to share information with the public. The focus was on presenting information in a clearly accessible format – both in the sense of laying one's hands on the information (a public website) and being easy to understand:

> The focus must be on providing parents with clear, meaningful and comparable information about student achievement across all areas of the curriculum in a format that is nationally consistent. Parents are entitled to honest judgments about how students are progressing at school, and without this clear communication, learning cannot be effective. (Commonwealth of Australia, 2008b: 32)

But this desire to inform publics and empower them to "make honest judgements" about student progress was not universally popular. Principals and teachers felt that entrusting this kind of expert information to inexpert parents would not be in their interest. But when school principals and teachers expressed these fears, Gillard responded strongly, saying "where information exists about the nature of students' learning, it is not appropriate that it should be held by some – professionals and administrators – and not available to the wider community" (Commonwealth of Australia, 2008a). She emphasised this point again, a year later:

> Parents want to know. I find it offensive to suggest that this information should be withheld or that parents are too stupid to know what to do with it. (Gillard, in Tomazin and Tovey, 2009)

Parents and the general public thus gained new information, and armed with this information, they became authorised to participate in the processes of accountability and steering at a distance. As I will describe later, this allowed various groups, each with particular anxieties and motivations, to present a variety of scenarios and to speak on behalf of different actors. Although this situation is the result of the actions of the regulators, the proliferation of interests, problematisations and voices became far too unruly – it encouraged the production of non-authority.

Challenging numbers: The productions of non-authority

When like-school comparisons were first made public, several schools found themselves classified with others they did not think were 'like' them at all. In some cases, large and small schools, and rich private schools and poor state schools, were cast as 'like schools'. These instances were gleefully highlighted in the media. In an article headlined "Teachers slam index comparisons",[1] one paper reported some 'mind boggling' comparisons made between very different schools. The ICSEA calculation became quite controversial as more and more unconvincing comparisons were reported.

One widely expressed dissatisfaction with My School was that the like-school comparisons were not *accurate*. The Sydney Morning Herald, a popular newspaper, published an article headlined "Principals reject My School site", that said "principals have given it a fail in a survey of

more than 1000 school leaders" (Harrison, 2010). It continued:

> More than 87 per cent of the 1166 public school principals who responded to the survey said they did not believe the website in its current form presented an accurate picture of school performance … more than a quarter of principals said they believed information published about their school on the site was not correct. (Harrison, 2010)

Far from being self-evident and convincing, the numbers still required 'belief'. The same survey also said that Principals questioned the methodology of like-school comparisons, and felt the calculations of index values were inaccurate and using those as a basis for similarity was not valid. The proliferation of views on this calculation made it unstable and diminished its authority.

The adequacy and validity of NAPLAN tests as measures for school comparisons were also challenged. The idea that a single snapshot account represented school performance irked many school principals and teachers. The wisdom of using standardised literacy and numeracy tests, which were fairly narrow in scope, as measures of student or school performance came to be widely debated. The Australian Education Union's journal Professional Voice produced a special issue called *The NAPLAN Debate* (Australian Education Union, 2010) with a series of essays on the flaws of NAPLAN and My School.

Even some parents, in whose name and interest measures of transparency had been developed, showed themselves to be fickle. They joined with teachers in pointing out that creating a causal link between the teacher and student performance failed to take into account that students would have been with a particular teacher for only a few months when NAPLAN was administered. Like Callon's (1986) scallops, parents could not be reliably 'enrolled' – they did not stick to script; instead, they began to improvise.

The Australian Education Union (AEU) was a particularly strong opponent of My School, fearing that the numbers on the website would be misinterpreted and misused. The AEU's 180,000 teacher members voted to boycott the 2010 round of NAPLAN tests, saying that the My School website would damage the reputations of some schools unfairly, on the basis of false calculations. This threatened the feasibility of conducting NAPLAN 2010 altogether, but an agreement was reached at the last minute. Teachers allowed NAPLAN to go ahead in return for a greater say in what was displayed on the My School website.

The most contentious of the calculations was the ICSEA index, whose accuracy, and the validity of its use in such calculations, continued to be queried. To quell the voices contesting ICSEA, Gillard spoke up, emphasising the complex technical and scientific nature of the calculations:

> We have obviously had public debate about the ICSEA index ... I do have a standing offer to any journalist who has read Barry McGaw's book on meta-analysis and would like to sit through and work through the regression equations with him, anybody who wants to do that, a standing invitation to come to my office for the number of days necessary to get that done. (Commonwealth of Australia, 2010a)

The expertise and reputation of the head of the newly established ACARA, Prof Barry McGaw, a highly regarded academic who had previously served as the Director of Education at the OECD, was called upon to boost the objectivity and believability of ICSEA. His reputation and scientific expertise also set him apart as bipartisan and apolitical, an arbiter of validity and a dispenser of unbiased knowledge. Moreover, Gillard suggests that the technicality of regression analysis creates a more believable set of numbers, and ordinary citizens and journalists needed days of instruction to become expert enough to appreciate these numbers.

Teachers' unions produced their own experts. Mike Williss, from the South Australian branch of the Australian Education Union attacked the very basis of the calculations on its own terms, rather than on the basis of any 'irrational' or emotional objections.

> The only honest thing about [ICSEA] is the word "community". . . ICSEA is not an accurate assessment of school similarity. School data is not used to construct ICSEA values. The data comes exclusively from what the Australian Bureau of

> Statistics calls Census Collection Data sets (CCDs) ... ICSEA values, for all intents and purposes, are measures of quite small communities. That is why ACARA is at least honest in stating that it is an index of communities, not an index of schools. (Williss, 2010)

Thus the very core of the ICSEA-based commensurability that supported the like-school comparisons came to be attacked. Debates ensued with regard to which entities were fit for inclusion in the calculations (for enrolment of entities into qualculations, see Lippert, 2018, this issue).

Organisations such as Save our Schools produced their own research reports.[2] Some organisations invited well-known experts and public intellectuals to address issues concerning NAPLAN and My School. The Australian Primary Principals' Association invited Dr Ken Boston to comment on NAPLAN and My School and provide cautionary tales about the negative effects they could bring in their wake, based on his experience with similar initiatives in England.[3] In this way more experts were called in to challenge the expertise that produced the numbers.

At the core of this controversy, we might say, was this question: Who is grown up enough for intimacy? The numbers generated by the Education Revolution might be 'objective' – but could the public be trusted to draw 'objective' conclusions based on it? Or would 'emotion' and 'prejudice' – the very things NAPLAN and My School were trying to counteract – rule? The capacity of the public to have enough understanding to make sense of the numbers in all their complexity and sophistication itself became a focus of debate. But Gillard was steadfast in her belief that parents were capable of understanding the data and using it responsibly, saying, "I absolutely reject the proposition that somehow I am smart enough to understand information and parents and community members are somehow too dumb" (Donovan, 2008).

Thus in these attempted assemblages of authority and non-authority, a range of factors, raised by diverse actors, faced a series of trials. The numbers stayed in the public arena, and so did the debates about the accuracy and validity of the numbers, and about who was expert enough to claim authority about this numeric knowledge. Both became part of the public debate. Intimacy not only with the numbers but also their shortcomings encouraged various groups to feel expert enough to challenge the numbers, the complexities of regression analysis notwithstanding.

The production of non-authority or partial authority did not just happen through any passivity or failure on the part of the government, but through vigorous efforts on the part of various interested actors who actively attempted to contest and to escape numbers.

Escaping numbers: The prospects for non-qualculation

The tug of war between the simple narrative being put forward by the government – measure, monitor, identify 'best practice' and train and incentivise teachers to use that 'best practice' to raise outcomes and eradicate disadvantage – was disrupted as more and more actors that were left out of this narrative were dragged back in. One of the most widespread concerns expressed after the introduction of NAPLAN was the stress experienced by students as NAPLAN approached. Children were reported to experience sleeplessness, bed-wetting and other manifestations of anxiety. Another concern was to do with teachers spending too much time on NAPLAN preparation at the expense of time on other subjects and activities. The concern over the feelings of students and teachers when their school is publicly shown up as doing badly was also raised.

One respondent on Gillard's blog[ii] raised a new issue with regard to possible negative fallout from these numbers and argued that:

> If the govt [sic] is aware of underperforming schools then they should fix the problem, not publicise it so parents can choose another school, thus creating a "second tier" of undesireable [sic] schools. Making this info available is simply encouraging people to treat the public sector like the private sector and force under resourced local public schools to compete for students like private schools. I think it's a disgrace.

So the wisdom of the Gillard government's plan of attack – transparency, accountability and the production of informed publics – was itself com-

ing under attack by informed publics. Discussion engaged with the outcomes and effects of these calculations and the possible damage they might bring in their wake. Thus the public engaged with the *performativity* of numbers (Gorur, 2016; Scott, 1998). In the matter of effects such as anxiety in children, parents possibly were in a more expert position from which to speak than the Education Revolution, which did not have any complex regression analyses with which to quell these emotional protests.

Where Gillard and others were promoting a single narrative that spoke of calculations yielding accurate and useful results which would lead to better strategy and tailored reforms, which in turn would raise the quality and equity of Australian schools, the involvement of a range of other actors brought in its wake a proliferation of narratives, issues and scenarios. The Education Revolution's emphasis on a single set of goods as what 'all Australians' wanted came to be dislodged as more – and more diverse – voices joined the debates.

However, these attempts to produce non-authority and to challenge and escape the numbers of the Education Revolution, while rigorous and wholehearted, were limited in their success. The challenges to the ICSEA calculations and to NAPLAN and My School resulted in some changes to the calculations and to what was presented on My School. But the Education Revolution's most salient features have remained, and so have the protests against them. Every year, especially around May, when NAPLAN is conducted, and in September, when the NAPLAN results are released, a spate of articles appear in the media, with titles such as "NAPLAN: The case against";[4] "Concerns over NAPLAN testing";[5] "Testing the test: NAPLAN makes for stressed kids and a narrow curriculum"[6]; "Parents concerned NAPLAN tests stress children";[7] and "Parents, principals concerned about the potential inaccuracies in NAPLAN results, research shows".[8] Some of these continue to challenge the calculations themselves, whilst others raise issues that are outside the calculations. A group called "Say NO to NAPLAN" has sprung up (see Figure 3), and their messages are hosted by another group called the Literacy Educators' Coalition.[9] The group reminds parents that their children do not have to do NAPLAN, and offer templates for letters to the Principal to exercise the right to withhold their children from taking the test.

Figure 3. Screenshot of the webpage of the Literacy Educators Coalition. Note the letters in red at the bottom, with the link to the parent letter, and above that, the letter of support from 140 academics across the country for Say NO to NAPLAN

So vigorous has the protest been against NAPLAN that a senate enquiry was set up in 2013 to investigate whether NAPLAN was effective, and whether it generated any unintended negative effects. The enquiry was initiated by the political party called The Greens. When the Senate Standing References Committee on Education, Employment and Workplace Relations called for submissions to inform its investigation, it received 93 submissions from a variety of sources. A public hearing was held in Melbourne in June 2013. The investigation produced a 50-page report (Education and Employment References Committee, 2014) with several recommendations to mitigate what it saw as the worst effects of NAPLAN. The report documents submissions citing examples of "a range of unintended consequences" which have resulted from NAPLAN testing, including "'narrowing of the curriculum' or 'teaching to the test'; the creation of a NAPLAN preparation industry; and adverse or negative impacts on students" (Education and Employment References Committee, 2014: 13). The committee recommended that:

> … ACARA closely monitor the use of NAPLAN results to ensure results are published to assist the Government to deliver extra, targeted funding to schools and students who need more support, rather than the development of league tables. (Education and Employment References Committee, 2014: 25)

However, the most prominent recommendations focused on the introduction of computer adaptive testing,[10] rather than the dismantling of NAPLAN or My School.

Thus the production of non-authority, or the bid to escape these numbers, was thwarted. NAPLAN and the reporting of like-school comparisons based on NAPLAN have now become routine and established annual features. Performing well on NAPLAN has come to be seen as important even by schools that claim that they do not believe NAPLAN provides a good or comprehensive account of student learning. Some state governments instituted measures that reinforced the authority of the Federal numbers by engaging in expensive, wide-spread reforms to raise NAPLAN scores. All over the country, workshops began to be held to train teachers in using NAPLAN data to inform their teaching. Thus, despite the vigorous challenges, these numbers have become thoroughly entrenched in schools.

Non-qualculability: Subversion and refusal

One way of thinking about this difficulty of displacing qualculations is that even when particular numbers may come to be challenged – even challenged successfully (for example, the first iteration of ICSEA) – the possibility of achieving calculation remains. A durable challenge requires that not just qualculation, but *qualculability* needs to be challenged. Callon & Law (2005) have proposed that the production of non-qualculability is difficult to achieve, and is rarely witnessed. They identify two possible situations in which non-calculability might be achieved: *rarefaction*, in which the resources for producing calculations are wilfully and actively removed, and other arrangements – such as a room and chairs and silence and bodies – are mobilised, as in the practices of Quakers' silent ministry; and *proliferation*, in which accounts of an event are multiplied to such an extent that a single summation or a definitive account become difficult to produce or sustain.

In the Education Revolution, neither rarefaction nor proliferation, it appears, are in evidence. Rarefaction is difficult when the actors involved are too numerous, too dispersed and too loosely connected to be effectively regulated. It is one thing for a small, intimate group of religious people to follow certain difficult rules and persevere in voluntarily acts of suppressing their selves and submitting to a higher spirit, and quite another to gets millions of parents to ignore NAPLAN or disengage from My School. However, a few parents *are* now choosing to keep students away from school on the days of NAPLAN testing, but this is, currently, an aberration and an exception. Even if more parents kept their children away from the test, the absences are unlikely to be significant enough to skew the data, and there would be nothing to stop the government from producing these numbers. There were no opposing agendas in the Quaker worship example, whereas in the Education Revolution,

multiple agendas are in play, making rarefaction nearly impossible to achieve.

Moreover, a particular difficulty with using rarefaction as a technique for the production of non-qualculation (and thus non-authority) is to figure out what material resources are needed to produce an *absence* (see also Neyland, 2018 in this issue). I would also argue that rarefaction works only if it *precedes* calculation – once calculation has been established, installing non-calculation in its place would be all but impossible, because calculation would need to be displaced before it could be replaced with non-calculation. Displacement of calculation would need to begin with an engagement with calculation – which would immediately destroy the prospects for the production of non-calculation (however, for a study of ignorance-in-practice as a way of disengaging with calculations, see Lippert 2013, chapter 4.4).

As to proliferation, Callon and Law (2005) argue that 'qualculation' involves a definitive summation – a s*ingle* definitive summation – that is more than momentary, and can maintain its currency for a period of time. Asdal (2011) also speaks of the power of a single number series. In the case of NAPLAN and My School numbers, even though they are updated annually, the numbers remain stable on the website for a whole year before a new set of numbers is produced. Indeed, the previous years' numbers remain on the website and are available to view in subsequent years – they are not replaced by the new numbers. Each new generation of numbers cumulatively produces new calculations of trends and narratives of growth and decline. The new numbers are not a threat to the old – instead, by accumulating within the same stable framework, they strengthen the assemblage (this resonates with Holtrop's (2018) account (this issue) of the ability of uncertain numbers to strengthen a policy report).

Examining the efforts to *escape* (which is distinct from *undoing*) the numbers in the Education Revolution, two strategies could be observed: *subversion* and *refusal*. NAPLAN was meant to provide 'objective' information because it was the *same* test administered throughout Australia. But some schools and some teachers provided more preparation for the test than others and made the playing field again uneven. This distorted or made less reliable the NAPLAN performance comparisons so dear to the Education Revolution.

So rampant did this practice of test preparation become, that in 2012, an investigation was ordered into allegations of 'excessive test preparation'[11]. Some schools were reported to be coaching their students a year ahead of the test, prompting the Federal Education Minister to emphasise that this level of preparation was not beneficial (for a more detailed discussion, Gorur, 2015c). However, the Minister's warning does not seem to have been heeded, because in March 2014, ACARA issued a statement banning principals and teachers from coaching students for the NAPLAN tests.

To further discourage coaching, for the first time, in 2014, ACARA did not disclose ahead of time what type of writing task – persuasive or narrative – would be assigned to students. This coincided with a substantial increase in the number of students who did not attempt the writing task in the test at all, and consequently scored a zero (the writing task is a significant part of the literacy test). Scores on the writing task fell across all the tested grades in 2014, following the non-disclosure of the type of writing task. The refusal to attempt the writing task meant that students had subverted the possibility of their writing skills being assessed. This thwarted the government's desire to track accurately the growth in students' writing ability across several points in their school life.

Some schools and teachers even began to cheat on NAPLAN, assisting students to complete the test or compromising the security of the test storage ahead of administering the tests. In the Australian state of Victoria, over 150 schools were found to have breached the rules, prompting a government crackdown on such cheating (Tomazin, 2013). In one school the principal was sacked after it was found that s/he instructed teachers to give the students as much time as they needed to complete their NAPLAN test. Indeed, schools found a variety of ways to cheat, including 'hothousing selected students to help the school get more students into the "higher achievement bands"' (Tomazin, 2013). Some schools encouraged students likely to score low in the tests to

stay away from school on NAPLAN testing days. In some cases, schools offered high performing students transport to school to ensure that they participated in NAPLAN in a bid to boost the school's NAPLAN scores.[12]

These strategies for "gaming the system" were widely reported in the media.

As a result of these breaches, new legislation was passed providing ACARA with greater powers to investigate cases of fraud. In 2014, 51 schools came under investigation for cheating in NAPLAN.

Parents also lost sight of their task of making schools accountable. Instead, they began to seek ways to improve their child's score – buying practice books or even engaging tutors to coach students so that they could get better numbers on NAPLAN. A range of businesses sprang up that claimed to improve students' NAPLAN scores.

These actions not only subverted NAPLAN by denting its claim to accuracy and objectivity, it also attacked the very purpose of NAPLAN, which was to 'shine a light' on schools, and identify and remedy low performance and reward high performance. High performing schools were to provide examples of good practice to low-performing schools with like populations. But if the strategies for better NAPLAN scores had less to do with pedagogy and more with corruption, high performing schools would be poor exemplars. The objective of doing NAPLAN shifted; both schools and parents appeared to simply want high scores for their students, perverting the possibility of getting useful information. A high NAPLAN number became an object of desire, and in their very acts of subversion, schools and parents appeared to embrace the number intimately.

Another method employed to escape the NAPLAN and My School numbers is to refuse or become a conscientious objector, or encourage others to do so. Some school principals suggest to parents that they might seek exemption from NAPLAN for their child, because taking the test would be too stressful for them.

Some parents are also, on their own, seeking such exemption. Such withdrawals from the test have been steadily increasing, along with reports in the media about the detrimental effects of taking NAPLAN. The 2014 round of tests had the highest rate of absenteeism in the NAPLAN tests[13]. In May 2014, newspapers were filled with the findings of a new report that suggested that NAPLAN testing could be detrimental for students. Headlines such as "NAPLAN testing 'not in students' best interests': report"[14] further encouraged a refusal to participate in NAPLAN.

Not only are more parents choosing to refuse NAPLAN by seeking exemption for their child, in an alternative form of refusal, some parents are no longer taking much interest in the test results. They are not eagerly studying their child's NAPLAN report to inform themselves on where their child stands against the national average and other data, or looking at the school's performance and following the progress of cohorts on My School. Letters in social media, endorsed in some cases by school principals, encourage parents to pay less attention to standardised testing, reminding parents that the distant assessors know much less about their child than the teachers who see them everyday.

In the Education Revolution, there is no 'single number' or a single number series that is produced – only relational rankings that schools aspire to achieve. The desired status is not a specific, stable number - it was a moving target. The fortunes of a school's rankings are, at least to an extent, out of its hands – its ranking depend on the situation of other 'like' schools. Perhaps having such a moving or relational target has contributed to the inability to 'move' either the schools or the numbers attached to them. Between 2008 and 2015, the period during which this study was conducted, NAPLAN results for the nation as a whole have not appreciably increased, despite significant expenditure on developing the tests, developing the website, and training teachers to use NAPLAN data in diagnosing students and modifying their teaching. Moreover, Australia's scores on large-scale international assessments have shown an appreciable decline (Thomson et al., 2016). Rather than prompt a rethink on the value of such measures for raising student performance, Australia's declining results in international assessments seem to only spur the efforts to measure and monitor and hold teachers and schools accountable. This may, in part, be the cause of the high attrition rate among teachers in Australia – a new addition to Australia's growing

set of problems in school education. Whether these developments will challenge NAPLAN and My School sufficiently to displace them remains to be seen.

Conclusion

The Education Revolution provides an empirical opportunity to explore how both intimate and distant forms of accounting can simultaneously operate, each reinforcing, rather than destabilising, the other. While the processes of distant accounting are well known and have been well elaborated in STS literature, Asdal's (2011) notion of intimate accounting actions have not as yet been explored in detail in different empirical settings. In this paper, I have shown how 'transparency' involved a violent form of intimacy that required individual schools to expose themselves to the general public in intimate detail, revealing what they might have preferred to keep hidden. The harsh glare of exposure permitted no shadows into which a school could escape. Intimacy became a right of the tax-paying public and of concerned parents, although their maturity for such intimacy became a matter of debate. Such intimate activity was no longer confined to certain locations, but spilled over through conversations into kitchens and living rooms.

Simultaneously, the Federal government set about reinforcing its capacity to steer at a distance. The practices of intimate accounting produced a new centre in the form of My School – a place where parents, the government, the students and the schools were all gathered in new relational arrangements. The My School website penetrated schools as well as homes – indeed the very name "*My* School" hints at the intimacy ambitions of the website. The paradox here is that it became possible to extend 'intimacy' to literally millions of actors. Everyone had access to the same numbers, and NAPLAN and My School entered conversations everywhere.

Interestingly, the processes of distant and intimate accounting not only co-existed, they both depended on the same calculations. The My School website is particularly interesting in its hybrid and multiple roles – on the one hand bringing together abstracted versions of distant schools and children and their test scores through its stylised pages into statistically similar neighbourhoods, and on the other hand, penetrating intimate spaces within homes and schools, entering into conversations in kitchens and living rooms, and creating individualised anxieties and ambitions.

The Education Revolution mobilised public interest in the numbers generated and placed its trust in these numbers as well as in the public. However, this trust was not necessarily reciprocal – the 'informed publics' did not unanimously trust either the numbers or the government; instead, they dragged back issues that the numbers sought to remove from the debate, hindering the production of a single number series or the formation of an immutable mobile which could endure challenges. Access to numbers enabled publics to feel so well informed as to produce damaging newspaper headlines and even force a senate enquiry into NAPLAN.

Behind all of this activity were the calculations – the NAPLAN results, the ICSEA calculations and the like-school comparisons. The more these numbers spread, the more numerous and diverse the actors they encountered, the more they came to be challenged. Not only was the accuracy and the meaning of these numbers challenged, but attempts were made to compromise the very conditions of calculability. Various strategies were used to make the calculations less stable and reliable. To Callon and Law's 'rarefaction' and 'proliferation', I have proposed that we could add 'subversion' and 'refusal' as two further technologies of non-calculability.

However, challenging calculability – or producing non-calculability – appears to be difficult to achieve at scale, and the efforts of the actors engaged in this assemblage were not sufficient to challenge the authority of the numbers and thus of the regulatory efforts. Despite the refusal and the subversion, the assemblages of calculation and authority rumbled on.

The contribution of this paper lies in its bringing together three STS concepts – Asdal's (2011) 'production of non-authority', Callon and Law's (2005) 'production of non-calculability' and Callon et al's (2009) 'informed publics', into new relations with each other as they encounter tech-

nologies of 'intimate accounting' in the empirical site of the Education Revolution. Playing with Asdal's (2011) work on accounting intimacy, I have elaborated various technologies of 'intimate accounting' which complement accounts of 'distant accounting' that are already well-established in STS literature.

Through this account of Australia's Education Revolution, I add to empirical stories of accounting intimacy in social policy fields, where such accounts from the field of education are relatively scarce. Despite their appropriateness to studies of knowledge making, there is surprisingly little use of STS concepts and methodologies in the field of education. This study adds to the small body of work in the field of education policy that is now engaging with STS. By the same token, it also contributes to the emergent body of STS work in the field of education.

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Respect for Numbers: Lively Forms and Accountable Engaging in Multiple Registers of STS

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Abstract

This paper explores an episode of numbers appearing on a screen and being read/spoken, looked at and received *as numbers*, by people who work together to achieve a particular goal. The events happened in Singapore, in 2012-2013, as part of periodic reporting on diabetic retinopathy screening in the context of efforts to innovate such screening. I tell of two parties at odds over how to engage numbers accountably. This question of 'engagement', of what can and should be *done* with numbers to secure their participation in organizational affairs, is worked out in how numerical forms are performed and sustained as working numbers. Using three STS analytics to analyse the episode – Helen Verran's (2001) work on number as a relation of unity/plurality, John Law's (1994) work on modes of ordering, and Steve Woolgar and Daniel Neyland's (2013) work on mundaneity and accountability – I argue that numbers are brought to life in very different ways, each mobilizing a certain recognition of what numbers *are* and what it takes to respect this. In the conclusion, I comment on the article's use and juxtaposition of these STS analytics, using the metaphor of a kaleidoscope.

Keywords: numbers, accountability, engagement, symmetry, STS theory

Introduction

In the midst of fieldwork on eye images, in January 2012, I witnessed an exchange over numbers that put me on the path of writing this article. This happened in Singapore, in one of the meetings of the interdisciplinary group whose work with retinal images I was following. 'Prof Xu', the group's leader, and PI for most of its projects, expressed dissatisfaction with the progress numbers being reported for its flagship project. The project meant to pave the way for a significant public health innovation: a new model for the delivery of diabetic retinopathy screening. So these numbers were important. But in the meeting, the professor did not like what he saw and heard.

A 'grader', about whose role I will say more below, had flashed up a PowerPoint slide with a numerical table, and had read out the totals-to-date flatly and matter-of-factly. The numbers had 'floated' into the room as self-contained utterances and notations on the screen, needing no elaboration. The professor wanted to see them *worked* more: in and through these numbers, he wanted to see where the project was headed; he wanted to glimpse projections into the future. He asked the graders to engage their numbers differently, to engage them *properly* so as to provide more insight. And yet, in subsequent meetings over the course of the following year, graders

reported their numbers in the same way. Numbers were sent into the room, only to be met by the request to be 'done' differently – and then the same thing happened again in the next meeting.

I was intrigued by these moments of 'disconnect', which added an element of tension to the meetings but also made the numbers central to them *strange*. When I say that numbers were sent into the room, that they were floating, I am choosing my words with care, to convey a sense of that strangeness, almost opaqueness, of the forms presented. Helen Verran (2001: 102) has reminded us that *numerals* – the spoken utterances or written shapes we use to denote numbers – and *numbers* – the entities that participate in practices of enumeration – are not identical. When we buy five oranges in a market or read about a 1% inflation forecast, our encounter with numerals immediately sets in motion familiar rituals of enumerating. For practical purposes, there is no distinction and we do not even notice numeral becoming number. In this fieldwork episode, however, the distinction was brought into focus. In what sense were these 'floating' numerals failing to come alive as numbers? In what sense were they indeed brought to life, but in a way that differed from what was recognized by the professor?

For those of us interested in pursuing an empirical philosophy of numbers and their relations, this number situation provides an opportunity to revisit the question of what numbers become in differing engagements. It provides for an investigation into the enacted ontologies and accountabilities that constitute numerical agency and organizational relations. What numbers are made out to *be* entails stipulations for how to accountably engage them. Vice versa, accountable engaging makes numbers consequential, brings them alive, by specifying their participation as numerical entities in particular ways of acting, being, and relating.

Using the grader's floating numbers as a provocative starting point, I will pursue a narration of the relationalities in and through which the parties in this fieldwork episode were 'doing' numbers *differently* and demonstrating how to do them *properly*. My analysis follows the lead of three STS analytics: Helen Verran's (2001) work on number as a relation of unity/plurality, John Law's (1994) work on modes of ordering, and Steve Woolgar and Daniel Neyland's (2013) work on mundaneity and accountability. There is family resemblance between these analytics, all of which see the properties of entities as not fixed but as relational and emergent, and all of which have an interest in how we may interrogate that which has congealed. At the same time, they offer different approaches to what we take as the number object and its performed properties in the episode under consideration. By bringing together the episode and these three analytics, I show how narrations of accountable engagement can recover liveliness in seemingly unanimated forms. This broadens into a more general point about how numbers are constituted as things to be reckoned with in engagements that mobilize a certain recognition of what numbers *are* and what it takes to respect this.

In the conclusion, I take these points forward in reflecting on the article's use and juxtaposition of STS analytics. In using my fieldwork episode as a 'comparison engine' (Beaulieu et al., 2007) for the analytics, the differences between them come to stand out by enrolling them as tools on the 'same' job. Doing this allows me to multiply the stories about agency, work, and taking care with numbers that I tell with my materials – much in the way a kaleidoscope presents an ordering of its pieces that is different with each turn, creating different patterns. Like Lippert (2018) who compares qualculation (Callon and Law, 2005) and Verran's (2001) juxtaposition of ontics and ontologies, I too see such a comparative exercise as a way of working *in* and *on* the analytics that are our shared STS heritage. Just like numbers, these analytics become things to be reckoned with in and through ongoing attempts to use them, faithfully and generatively. The article's specific contribution to STS scholarship on numbers and numbering is then also accompanied by a broader message regarding ways of doing STS.

Lively numbers: Inscriptions and enumerated entities in STS

By way of situating the theoretical question of how numbers come alive in our engagements

with them, let us revisit how the agency of numbers has been described in other STS literature, particularly in approaches associated with actor-network theory and post-ANT. Treatments of numbers as 'inscriptions' and as 'enumerated entities' each teach us about the relational configurations in which numbers emerge (or fail to emerge) as effective and properly utilized.

In understandings of numerical forms as inscriptions that help to produce reference and action-at-a-distance, the agency of numbers is part and parcel of the process of translation. This is facilitated by what Bruno Latour (1999: 49), in "Circulating reference", an account of a field expedition into the Amazon, calls "empty forms". A grid superimposed on the forest, tags attached to specimens, the protocol whose steps are followed in sequential order for the collection of earth samples, a filing cabinet that classifies as well as shelters materials – these methodological-material devices are empty until, as a result of their practical use in the field, they get filled. In the practical action of choosing and filling them, something is preserved and something is left behind. This is what 'circulating reference' means: the *movement* along a chain of translations, so that, in this case, a question about the behaviour of forest and savanna becomes answerable. Empty forms "are set up *behind* the phenomena, *before* the phenomena manifest themselves, *in order* for them to be manifested" (Latour 1999: 49, emphasis original).

Numbers play a crucial part in the work with empty forms, to the extent that these forms are set up to receive only or mainly numerical information. Latour leaves this implicit, but the point is made explicitly in Rolland Munro's (2001: 479) piece on budgets as accounts: "inscriptions in the form of budgets arrive on a page *as* numbers, not narrative" – thereby materially specifying what an account (in respect of the budget) can contain, and what is excluded from it. The spreadsheet is an empty form that *calls for* numbers. The numbers entered into it obtain their relevance and appropriateness from the way they are presented as form and as substance: because they are formally right, they can become empirically significant. In a similar vein, Paolo Quattrone (2009) writes about *figuring* in the accounting practices of the Jesuits as powerful by its emptiness. The empty form of the ledger, which calls for numbers to fill it, structures the thinking and creative practice of accountants: "its content may be absolutely evanescent, while the form appears to be clear" (Quattrone, 2009: 112).

Returning to Latour's work on circulating reference: once a form is filled with actual numbers – location nr. 234, sample nr. 3 – empirical faithfulness becomes an important thing to preserve: "If I were to tear down these [numbered] tree tags, or if I were to mix them up, Edileusa would panic like those giant ants whose paths I disturb by slowly passing my finger across their chemical freeways" (Latour, 1999: 32). So numbers can be thought of as 'working inscriptions' if they do their part to keep the chain of reference intact. In this way, they participate in producing the possibility of faithful representation and power, of 'action at a distance'. The chain breaks, however, when numerical inscriptions' function to *preserve* is severed from their function to *translate*. This is what would happen in the imaginary scenario of mixing up the number tags. It is also how we can read social psychologist Diederik Stapel's account of messing with survey numbers: a pivotal moment in the research fraud he committed. When in the privacy of his office he "changed an unexpected 2 into a 4; then, a little further along, […] changed a 3 into a 5" (Stapel, 2012: 102), reference could no longer circulate.

Related accounts of failure appear in studies that attend to the practical difficulties and contingencies of getting numbers-as-inscriptions to facilitate action-at-a-distance (Asdal, 2011) or produce an influential account (Neyland, 2012). These studies understand both success and failure in more situated terms, yet retain from Latourian studies of science-in-action the sense that numbers' agency as inscriptions is a function of their participation in and connection to a chain of translation across which objects of knowledge or concern are transported.

Training our attention on a specific set of numbers rather than the entire chain – 'freeze-framing' them – is, on this view, not helpful. However, another body of literature treats numbers as entities and asks after their agency or participation in situations of numerical sense-

making, thus ostensibly ignoring this proscription. Helen Verran (2012: 66) understands numbers as "lively material-semiotic actants" – where "lively" relates to the way they work as signs, in practice. Verran argues that numbers can work in inventive ways by shapeshifting. Or, arguably, by shifting everything *but* their shape: they may look the same but are different in their way of "materially expressing formal relations" (Verran, 2010: 173), in how they *generalize*. Attending to the 'liveliness' of numbers here means understanding and being able to interrogate how numbers participate in ordering and valuing, and it means keeping number-facts connected to the epistemic practices through which they are generated. Being specifically concerned with the relationship between knowing and policy-making, Verran (2012: 68) argues that numbers are no longer 'lively' when they "have zero temporal extension", when they no longer can be taken forward or revisited as active participants in knowing and governing. For example, a proprietary quantitative assessment deployed to fortify a government decision in relation to a dying Australian river, can be critiqued in understanding its functioning as a "solidified value icon" (Verran, 2012: 68).

Dawn Nafus (2014), writing about the numerical data generated by sensors, uses the term 'liveness' (adopted from Lury, 2012) to articulate something similar. 'Live' here captures a sense of "numbers-in-production" or "in the making" (Nafus, 2014: 211), of becoming that carries possibility and the capacity for surprise. The other side of this is the uncertainty as to whether numerical data will attract the kinds of labour that bring and keep them alive, whether "calculative infrastructures" will "cohere" or whether these numbers that are "free for the taking" will "more likely […] betray, fall flat, or find dead ends" (Nafus, 2014: 221).

Making numbers as entities the point of entry for analysis, and using the affective language of liveliness and its antonyms, provides a fresh take on ways in which numbers make a difference or fail to do so – in other words, on the politics of numbers. In this and related work, two qualities are associated with lively numbers: they are able to *effect* – that is, to be taken into account, to be taken seriously in relation to an action or decision – and they *remain open to interrogation* - that is, are not solidified, reified or naturalized in ways that obscure how they are made to signify. They live in the paradox of stability and instability, being stable enough to effect, yet unstable enough to be interrogated. Tjitske Holtrop (2018), in her article on the number 6.15% in Dutch foreign policy interventions in Afghanistan, captures these two sides aptly:

> Importantly, numbers are caught in an oscillation between evoking referential doubt and evoking confidence or action (until they don't anymore and someone or something throws the numbers back into a pool of questions and uncertainty, demanding clarification, and so on). Rather than weakening the power of numbers, it is in this contradictory oscillation, as interface, that numbers are generative. (Holtrop, 2018: 86)

Substantively, at least in my reading, this paradox or oscillation retains a version of Latour's dual emphasis on preservation and translation in articulating what makes numbers work. At the same time, methodologically, the shift from considering numbers as inscriptions to numbers as 'lively material-semiotic actants' expands the possibilities for analysing numbers' relational agency in knowledge-practices. By positioning numbers as protagonists in our ethnographic stories, we are not confining them to one role or way of being. When numbers are spoken of as 'participants' (Verran, 2012), as attractors of human labor (Nafus, 2014) and as entities that "have a form and a way of life that can be explored ethnographically" (Holtrop, 2018: 78), this brackets the assumption that we already know what numbers are or what they do. Such methodological agnosticism works from the position that we will never fully know our numbers, fully pinpoint or control their participation in our collective affairs, or successfully reduce them to one thing. It retains the capacity for surprise, for engagement to unfold in surprising ways.

This literature on numbers as inscriptions and on numbers as enumerated entities has paved the way for understanding numbers' agency as the upshot of practices of producing reference and action-at-a-distance, and of rituals and practices of enumeration. Importantly for the purposes of this paper, it has also paved the way for under-

standing number forms as needing activation so that they do not fail or fall flat. In what follows, I build on this heritage and language to narrate fieldwork materials as multiple forms of accountable engagement with numbers. In achieving faithfulness to numbers as particular kinds of entities, such engagements secure their participation and liveliness in organizational affairs.

A note on materials and methods

The flagship project I studied as part of my fieldwork on eye images between 2010 and 2014 aimed to make eye screening for diabetics in Singapore into a more streamlined and centralized endeavour. To do this, the appraisal of screening images was shifted from family physicians in local polyclinics to dedicated technicians called 'graders' in a grading centre. Graders, most of whom were hired fresh out of polytechnic education, were trained on the job for this work. Centralized grading by graders was projected to improve the reliability, speed and cost-effectiveness of screening services (Bhargava et al., 2012; Nguyen et al., 2016). This could then extend the reach and uptake of such services, meeting the needs of a population in which diabetes and its vision-relation complications were on the rise (Goh et al., 2015).

The project started by having graders take on the screening load of two polyclinics, and then gradually expanded. As the number of graders increased, the grading manager began to assign specific individuals the job of reporting progress numbers. At the heart of my account below are four meetings in 2012 and 2013 during which such reporting was done. My understanding of the graders' relationships with numbers is further based on two visits (in June 2013 and January 2014) to see the graders process numbers and hear them talk about what they were doing; and on two presentations of my own – one to the graders and one to the management team – in June and July 2013, in which the reporting of numbers was surfaced as a side-matter for discussion.

The mutual puzzlement with which the graders and the professor regarded each other's orientation to numbers, features centrally in my analysis: I use it as a path into articulating two quite distinct worlds organized around accountable engaging with numbers. The episode invites this, in that it brings to the fore a difference between the graders' actual way of doing numbers and the PI's preferred way for the graders to do numbers. In other words: the difference between 'doing it this way', and 'doing it that way' was a topic in these meetings – the 'proper' approach was at stake. At the same time, it's important to stress that my reason for dwelling on this is philosophical and methodological; it is not to give it special descriptive importance in the overall trajectory of this team's work. In terms of that trajectory, there is no reason at all to fixate on a set of meetings and reporting practices that have long since been reorganized, by now probably multiple times over.

What the 'disconnect' provides for us here is a provocation regarding what qualifies numbers as alive in our engagements with them. Is it possible to approach the graders' and the professor's expressed relations with the progress numbers as alternative ways of 'doing' numbers properly, and if so, what might that look like? By engaging three STS analytics in this work of symmetrical redescription, different aspects of accountable engagement are brought into view. At the same time, the episode of the disconnect helps to make these analytics comparable, and brings out the uniqueness of each by providing common ground for putting their symmetrical redescription capacity to use. As with all comparisons, "[a] unit for comparison has to be constituted, and features for comparison have to be specified, if this approach is to yield interesting insights" (Beaulieu et al., 2007: 677). This then is the particular way in which analytics and empirical materials are mutually elaborated in this article.

A disconnect

The progress meeting on 5 March 2013 attracts more people than usual. The room at the Institute is far too small for the thirty people who are trying to fit in it, so another room is found. Even here, people barely fit as we wheel in chairs and arrange ourselves in two tight rows around the conference table. A copy of a set of PowerPoint slides with numerical tables is distributed as a handout. Some lunch food is passed around.

The graders know what is expected of them: when it is their project's turn, they will present a progress update, in numbers. Their audience is a heterogeneous and shifting group of people that includes: the scientists who oversee the research grading, the grading manager and other administrators involved in the operations of the image analysis centre, the centre's IT staff, one or two business development managers, two or three computer scientists from a local university who are working on the automation of image analysis, and myself, a sociologist from the same university. The key audience for the graders' accounts is, however, 'Prof Xu', the clinician-scientist who heads the centre and is the PI on most of its projects.

Today, the flagship project, a pilot programme that centralizes and streamlines screening for diabetic retinopathy, is first in line. 'Khim , a grader who has been at the centre for a year and a half, is tasked with the progress presentation. When the corresponding PowerPoint slide appears on the screen, Khim reads out the numbers:

> In total we have seen **nineteen thousand one hundred twenty-seven** patients, of which **four thousand five hundred ninety-five** were referred and **one thousand nine hundred fifteen** were rescreened.

While Khim reads the numbers, everyone looks at the table on the screen (reproduced as Figure 1). Her reading directs us to three numbers in the table: 19,127, 4,595 and 1,915 in the last row..

These are 'total' numbers of patients, first the overall total (*nineteen thousand one hundred twenty-seven*), and then the breakdown by outcome of the screening examination. This outcome takes one of three possible forms:

- **Referral**: patient referred to a specialized eye hospital for further tests and/or follow-up care (*four thousand five hundred ninety-five*);
- **Rescreen**: patient asked to come for another round of screening in six months' time there are signs of diabetic retinopathy, but these do not warrant acute follow-up (*one thousand nine hundred fifteen*);
- **Annual**: patient assigned to continuous routine monitoring via annual screening, eyes look stable. (not read out)

Patients are assigned to one category or another based on so-called referral criteria.

In the progress meeting on 5 March 2013, Khim's way of presenting the numbers is recognizable to other participants as the typical way graders present their numbers. In the short silence after she concludes, people wait to see if Prof Xu will comment on this presentation.

For over a year now, Prof Xu has been intervening in the graders' presentations. These interventions are fairly explicit. When he says, addressing the grading manager that "We need to train the graders to find trends in the numbers, so that they don't just give us the raw numbers" (in the meeting of January 2012), it is clear that he wants something different than is being offered. He is indicating that the graders' numbers do not make see-able or appreciable what he wants to see or appreciate. Numbers are made present, but no story is told with or about them. All the numbers in the table are presented as if on the

Pilot DR Screening Service - Polyclinic Figures

Year	No. of Patients	Referral	Rescreen	Annual
2011	10,618	2,906	1,143	6,569
2012	7,799	1,577	771	5,451
2013*	710	112	1	597
Total	19,127 (100%)	4,595 (24%)	1,915 (10%)	12,617 (66%)
*Until 31 Jan 2013				

Figure 1. Progress update for the project.

Year	No. of Patients	Referral	Rescreen	Annual
Total (2011)	10,618	2,906	1,143	6,569

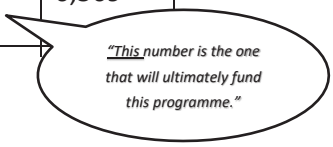

Figure 2a. Emphasizing the Rescreen number.

same plane – nothing is highlighted or singled out. And the graders are usually reticent to engage with follow-up questions. It's as though the graders present their numbers without an understanding as to what they are really for, or about.

A more extensive flashback to January 2012. After sitting through a reading of graders' numbers, Prof Xu walks up to the projection screen and points to the total for 'Rescreen' (Figure 2a). Tapping it with a finger he declares: "This number is the one that will ultimately fund this programme." His demonstration brings texture to a previously flat display, lifting out one number at the expense of others.

Prof Xu ties *this* number to the story of the flagship project, to its rationale. The Rescreen category is a key innovation within this new way of doing screening. It is a monitoring category, allowing patients who do not need immediate follow-up to be called back for a repeat screening in six months' time as opposed to one year ('Annual'). It gives screeners an option in-between referring someone to specialist care and having them continue routine annual screening.

'Rescreen' has been introduced to take some pressure off the 'Referral' category, allowing the system to reduce unnecessary demand for specialists' time and resources. In his demonstration at the screen in January 2012, Prof Xu also points to the Referral number as deserving special attention (Figure 2b):

> This is the number that needs to remain low or get lower. I don't mind if the other two numbers stay large; it doesn't matter whether it's six months or twelve months, as long as it's not referral.

By singling out some numbers rather than others, Prof Xu elaborates the relation between numbers in a way that connects them to the aims and objectives of the pilot programme. The Rescreen and Referral numbers are crucial in building the case for this programme.

Back to March 2013. After Khim has read out the total counts as of 31 January 2013, Prof Xu asks a question. Looking at the screen, he asks: "Why was there a drop for the Rescreen category in 2013?". The question hangs in the air, is for a moment met by silence. It has a similar effect as his earlier gesturing: it singles out one number. From being invited to take in *all* numbers on the same plane, our attention comes to be directed to *this* number: the number '1' in the Rescreen column (Figure 3).

Khim offers, in a low voice, that "it was because of a change in the referral criteria". This exchange, again, goes back a long way. The referral criteria are decision criteria that create cut-off points between the categories. In the previous year, a committee in which Prof Xu took part revisited these criteria and decided to make them more

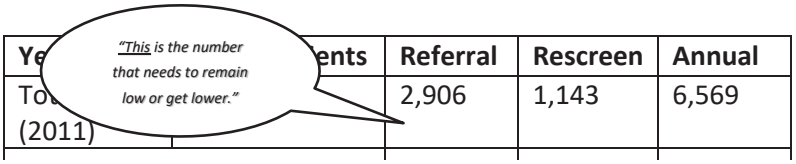

Figure 2b: emphasizing the Referral number

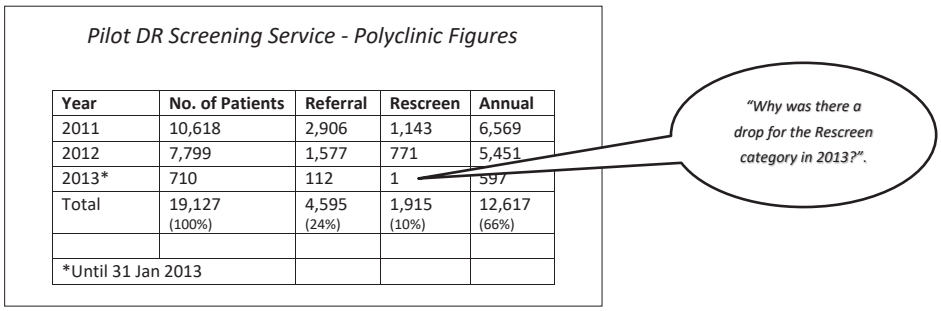

Figure 3. Singling out the Rescreen number for 2013.

conservative. The shift of the work of screening from doctors to graders made the committee nervous about false negatives, so it put safeguards in place to avoid cases that needed intervention ending up in the six-months rescreen category. Some patients who would have previously qualified for 'Rescreen' now had to be assigned to 'Referral'. This change in the referral criteria would naturally make it harder to achieve the project's projected savings of resources.

Prof Xu wanted to see the impact in the numbers' presentation. He had already requested this once before, saying in September 2012 to the grading manager:

> You need a slide to compare the numbers before and after the moment when the referral criteria changed. The graders are not presenting the right stats. They don't know how to ask the right questions. It's not their fault but it is a problem, because these stats won't drive change.

The exchange between Khim and Prof Xu on 5 March 2013 ends with, as far as the latter is concerned, the matter still unresolved. The change in the referral criteria has not been marked in the numbers' presentation.

When I asked the graders on a separate occasion what they made of Prof Xu's persistent questions and comments about their number reports, one said: "We hear that he wants something, but we are not clear on what he wants." Coming up with an adequate response to the issue was considered hard: "It would be good to think strategically about what he asks, but this requires a lot of time and coordination." Another grader, in a one-to-one conversation about his work with the progress numbers, ventured a guess about what the professor might be after, but also expressed limited interest in it:

> Maybe our referral rate is high? I'm not very sure. In any case, we don't think about it when we grade. Not to say that it's not our concern. But we have to grade without bias.

Another added: "You don't want to present something that's not correct."

We now turn to our three STS analytics to elaborate the relations of accountable engagement that make for two such different ways of doing numbers properly.

With Verran: Number as unity/plurality relation

In *Science and an African Logic* Helen Verran (2001: 94) teaches us to become attuned to the 'doing' of number in particular ways, to attend to "what numbers are in terms of here-and-now routines of practice, [of] ongoing collective acting". In this material-semiotic approach, which focuses on the forms of generalizing numbers take in practice, a key emphasis is on their enactment as unity/plurality relations. The story of the Reverend Alexander Akinyele's method to achieve an accurate census count of inhabitants of a town in Yorubaland in 1921 provides an illustration of this. Akinyele's method was to ask the headman plus one man and one woman from each community to *name* every man, woman and child in each household, to *represent* each name by a stone, and then to *count* the stones afterwards. He proposed this to the British colonial government as a workable way of enumerating the community: a series of translations designed to produce a census count accord-

ing to what the British understood such a thing to be, yet also faithful enough to Yoruba practices of enumeration.

> As Akinyele tells it, first there was the repeated making of a *unity*: a person steps forward, or a name is uttered, and a stone is placed. The routine is repeated until the set of people is exhausted. Persons are translated as pebbles. Second, a *plurality* is made as the stones are taken as a collection, which like collections in this way of numbering is taken to exhibit the quality of numerosity to a particular degree, a degree that can be represented with a number. Third, this number is rendered a *unity*: the population of a compound entered as an object into its place in a chart. Fourth, a further *plurality* is made as the numbers from many compounds are collected, to enable a fifth step, a further *unity*, the population of Ibadan, and so on. (Verran, 2001: 99)

In Akinyele's method, persons and populations are constituted in and through the alternating movement of making unity (categories) and making plurality (members of categories). Elaborating such "banal material practices" (Verran, 2001: 101) reminds of Latour's writing on chains of reference with their consecutive translations (small 'jumps') from matter to form (Latour, 1999: 49). But in Verran's tracking of units and plurals, the emphasis is as much on making *numbers* as it is on making reference. It is on doing numberliness in and through "routines of gestures and utterances [and] ritualized repetitions" (Verran, 2001: 100). In the momentum that makes units out of plurals and plurals out of units, numbers come to acquire their distinct capacity to generalize.

How does this work for the diabetic retinopathy screening numbers? Their journey up until their presentation by graders in the meeting, may be broken down into four moves of making unity and plurality. The 'making' relies on graders' actions amidst an infrastructure that includes computer hardware and software, a flow of images from polyclinics to the centre, and a number of organizational devices such as patient identifiers, protocols, and electronic logsheets. In stylized form:

- Graders make referral decisions out of their work with retinal images. This is the first move: producing decisions as *units*.
- At the same time, graders gather these decision-units into types ('Referral', 'Rescreen', 'Annual'), so that now each single decision is a member of a collective named after that type. This second move produces *plurals*.
- Graders add up the referral decisions within each collection to a category count: the total for 2011, 2012 or 2013. Thereby, the plurality of members is converted into a singular degree of numerosity. This is the third move, producing *units*.
- Graders gather the counts for the categories of 'Referral', 'Rescreen', 'Annual' into a new collection, that of 'progress figures' for 2011, 2012 or 2013. The is the fourth move, producing *plurals* again.

With the next move, the graders and the professor part ways. With Verran's emphasis on how numbers come to generalize, we can pinpoint how, during the meeting, numbers are enacted in two different ways.

- Graders convert the plurality of 'Referral', 'Rescreen' and 'Annual' for the years 2011, 2012 and 2013 into grand totals of singular numerosity (hence, new units) for the project-to-date, as of 31 January 2013.
- But the professor also wants them to make a different fifth move, which is no longer about adding but about comparing. He wants the plurality of 'Referral', 'Rescreen' and 'Annual' for the years 2011, 2012 and 2013 to be converted into units of relative share out of 100.

The difference lies in how units and plurals are made to stand in relation to one another. By putting all numbers on the same plane – treating them equally – in the table, and by reading out the grand totals for the project to date, the ritual set in motion by the graders is one in which the numbers in the table are recognized as *category counts* within the here-and-now *volume of work* produced. The 'whole', as the sum of its parts, stands for where the project is *now*, which is a different number from what it was three months or a year ago, or will be three months or a year from

now. The total volume is a momentary snapshot of the extent of work the graders have presently delivered for the pilot service. (Note that percentages are added in the same cells as the sums, perhaps in response to Prof Xu's earlier requests, but these are not elaborated in the presentation.) The graders have done their numbers as tallies, have configured themselves as tally-keepers, accounting in real time for how their work adds up.

When the professor asks questions, makes comments and uses gestures to highlight certain numbers in the table, he sets in motion a different ritual: one that recognizes the numbers in the table as (relative) *weightages*. This is done by indicating that it is the *relation* between numbers in the different categories that matters: "This is the number that needs to remain low or get lower. I don't mind if the other two numbers stay large; it doesn't matter whether it's six months or twelve months, as long as it's not referral." It is also done by comparing that relation in the present to that relation in the past ("Why was there a drop for the Rescreen category in 2013?") and in the future ("needs to remain low or get lower").

The professor has performed the graders' numbers as would-be trend numbers in a ritual that produces difference with the graders' own enactment on multiple counts. This ritual is faithful to numbers by imagining the whole before the parts: "a vague general whole that allows articulation of specifiable parts" (Verran, 2007: 181; cited in Guyer, 2014: 159), the 100% against which clear parts, as proportions, can be outlined. The 'whole' is what provides for the relative weight of the member categories to be calculated and projected into the future. That future is one in which the project will be assessed for achieving cost- and other benefits in the way it delivers screening. It is the future in which the Rescreen number, relative to the Referral number, "will ultimately fund this programme". The professor's number ritual not only produces a different temporal orientation to the numbers on the screen than the graders' ritual does. It also produces a different normative regime in which numbers are reckoned with as 'good' or 'bad' via the monitoring of their internal relations over time. What is more, it produces the requirement for the telling and retelling of these internal relations in relation to the project's aims, and for the graders to perform such telling.

Juxtaposing these two ways of making plurals into units, of relating unity to plurality, shows different ways of reckoning with numbers in taking stock of progress. One – the professor's – sets the stage for attaching consequence and possible action to these numbers, while the other – the graders' – makes this less central, being an accounting for the work that has been completed. This, by the way, is not to suggest that the graders were never moved to action by their numbers. One grader, 'Shawn', showed me how he scrutinizes his monthly totals to keep an eye on the 'ungradables' – images whose quality is too poor to be graded. The ungradables do not produce a decision and therefore do not end up in the specific progress statistics presented at the meeting. In relation to these images, Shawn said: "I find it most disturbing if I have a lot of ungradables. I sometimes need to reach out to the nurses, [remind them] how they should use the system. Show them what's ungradable." An increase in *that* number was something he looked for and acted on, by contacting the nurses (with whom he had developed a good working relationship) and trying to get them to produce better-quality images.

Using Verran's analytic , which describes multiplicity in how numbers are made to generalize, we can discern in the 'disconnect' two different ways of doing number, characterized as different unity/plurality relations. These make for different temporalities (past work vs future-oriented aims) and different forms of accountable engaging on the part of those responsible for the numbers.

With Law: Numeracy and discretion in different modes of ordering

In *Organizing Modernity* (1994), John Law uses the term 'modes of ordering' to refer to material-semiotic arrangements that "tell of the character of agency, the nature of organizational relations, how it is that interorganizational relations should properly be ordered, and how machines should be" (Law, 1994: 20). Modes of ordering, in other words, help describe how material relations and forms of agency are mutually constituted. In an

example that implicates numbers in the work of management, Law (1994; 1996; 1997) shows how spreadsheets participate in producing managerial discretion, because they enable a way of 'seeing' the organization. At the same time, they also circumscribe such discretion, because the shortfalls manifested in and through the spreadsheet need to be attended to.

Two of the four distinct modes that Law (1994) formulated, based on the talk, action and material organizing he encountered in his ethnography of the management of a scientific laboratory, are especially salient to my analysis: 'enterprise' and 'administration'.[1] Each mode envisions the world of the organization differently, and in doing so provides for particular ways of sense-making and normative assessment of action and situations.

Graders, when asked how they prepared for the progress meeting, said that the most important thing was to provide "an overview" of the project. Providing an overview is what the graders understand themselves to be doing as they extract the case records from the log sheet, filter them by month and referral decision made, add up totals for the year, and enter these into a table on a PowerPoint slide. As I watched one grader work with numbers to complete this last step, she commented: "I am just keying them in." It sounded almost like an apology, as in "sorry I can't show you something more interesting". But this indicated straightforwardness and simplicity is also the point: nothing else is done other than faithfully passing on what was found in the records.

With Law, we can say that these comments, these actions, this way of organizing work enact both graders and numbers in the mode of *administration*. This is a bureaucratic mode that heralds a strong emphasis on (due) process and on *correctness*. 'Correct' was indeed the term used by one of the graders when I asked for her response to the professor's requests for different numbers: "You don't want to present something that's not correct." Correctness is about ensuring accuracy: the grading manager checks the numbers before the meeting (and in other work of compiling numbers, graders apply checks and balances to avoid making any calculation errors). It is also about staying within one's remit and not getting creative: "I am just keying them in." Constituted in relations of administration, graders are 'correct-overview providers', faithful to their 'correct-overview numbers'.

A physician, a scientist, a managing director, Prof Xu must strategize and negotiate, make decisions, write papers, prepare keynotes, see patients. He often joins the meetings late, rushing in after his last appointment, and, afterwards, rushing to the next. He wants to keep things moving. As progress reports are being presented, he listens to determine whether there is a need to intervene. Does this project need help of any kind? Does a sluggish collaborator need prodding, a new data analysis strategy formulating, a new source of funding finding? Should they pull the plug on a project that no longer interests people, no longer pulls in investments of money or time? His organizational world and he himself as a decision-maker are 'made' in the relations of enterprise. The mode of enterprise, as Law (1994: 75) describes it, "tells of deploying resources, of adaptability, and of riding with the punches". Acting in this mode involves seizing opportunities and staving off threats in the process of moving forward.

In the mode of enterprise, numbers become organizationally salient as materials in and through which opportunities or problems are ascertained. When the professor singles out specific numbers as being of special significance and asks to see 'trends', he enacts numbers in the mode of enterprise. In and through the numbers, the professor is looking for indications of whether the flagship project is bearing fruit. The progress numbers on the screen are possible sites for intervention, a "place of discretion" from which to see and act (Callon and Law, 1995: 494).

A way of presenting that places equal emphasis on every number is not satisfactory in the mode of enterprise. Instead, in his gestures and elaboration, the professor enacts the 2013 Rescreen number as "too low", as prompting the team to strategize on what to do next. In the mode of enterprise, numbers need to be displayed in such a way that threats and opportunities become visible. In this mode, the progress numbers presented in the meeting are elaborated as 'drive-change numbers' – a phrase taken from the professor's comment that the graders' stats "don't drive change". If the stats do not show the impact of the change in

referral criteria on the relative proportions of Rescreens versus Referrals, they do not support corrective action. These numbers need to indicate possible trouble, for, in the mode of enterprise, "failure is a practical matter – something to be put right by trying again. For there is no such thing as absolute failure. Rather, there are setbacks and strategic withdrawals." (Law, 1994: 75)

Comments like "it's not their fault" and "we need to train them" constitute the graders as learners who can progress; they also chart a particular kind of future. By "present[ing] the right stats" and "ask[ing] the right questions" graders can constitute both their numbers and themselves in the mode of enterprise. In and through their numbering, graders have the chance to make their value visible: both their value as diagnosticians for diabetic retinopathy (who work faster, more accurately, and more cost-effectively than generalist-doctors) and, at the same time, their value as enterprising subjects. The professor calls it "moving us all up the value chain."

Indeed, the stakes of being able to engage numbers in the mode of enterprise become clear in the context of nation-wide initiatives that have sought "to entrench a culture of productivity and continuous learning and upgrading in Singapore".[2] These foreground a particular kind of "thinking people" (Teh, 2012), in constant search of opportunities to 'add value', as exemplary employees – a model that extends to those, like the graders, in entry-level jobs.[3] By enacting the progress statistics as 'drive-change' numbers, the professor holds these up as a prime site (though not the only one) for the graders to cultivate themselves as 'thinking' persons, to participate in seeing and showing opportunities and threats, to help make the case for the pilot service. Graders who engage numbers in the mode of enterprise thereby also indicate their own staying power in the world of work, even as developments in automation or artificial intelligence may put them out of their primary job.

So the mode of administration and the mode of enterprise operate with different values to anchor accountability: correctness in the first and opportunity/threat/action in the second. By having their numbers critiqued in the meetings, graders are asked to straddle the two. Juxtaposing the two modes in relation to the concerns that animate the project also allows us to bring into view another aspect. Remember how Shawn cared about the number of 'ungradables', those images whose quality was too poor to be graded? He kept watching this number in case it prompted him to talk with the nurses about better use of the retinal photographic camera. Shawn could not see how he might develop a similar relation to the progress numbers prepared for the meeting, which, as he said, "to me don't mean much". He took a guess at the professor's concerns – "maybe our referral rate is high?" – but he also drew a clear line: "Not to say that it's not our concern. But we have to grade without bias." Working with these numbers in terms of what the desired outcome might be, something Shawn was motivated to do for the ungradables, he saw as problematic for the progress numbers. Grading without bias is a matter of correctness and of vocational pride: Shawn seemed to take pride in not caring about these numbers, not going beyond 'correct overview', because doing so might interfere with his ability to do the work of grading at the core of his job. Here being 'correct' has a hint of the moral high ground as well as asserting a relation of accountable engaging marked by self-imposed disinterest in what these numbers "mean".

Recourse to the analytics of modes of ordering has made it possible to examine the co-constitution of numbers and calculating subjects in how things get done and accounted for in organizations. In the different 'modes', numbers become organizationally salient as 'correct-overview' numbers or 'drive-change' numbers – with their respective ways of delineating appropriate actions and demeanours for calculating subjects. By allowing us to attend to both the organizational positioning of and the normativities inscribed in number work, modes of ordering provide a sense of the stakes and obduracies of the disconnect.

With Woolgar and Neyland: The self-evidence of numbers

The third and final analytic we will bring to bear on this case comes from Steve Woolgar and Daniel Neyland's (2013) book *Mundane Governance: Ontology and Accountability*. The way in which ontology and accountability are brought into double focus in this book provides another opportunity to articulate features of the disconnect. This approach is interested in "the accomplished ontology of entities" (Woolgar and Neyland, 2013: 51), the temporal fixation and distribution of identities. It has a particular focus on how such fixation and distribution is part and parcel of enacting moral orders.

An example is the case of the woman who sued MacDonalds for serving hot coffee, aggrieved after she had spilled the coffee on her lap (Woolgar and Neyland, 2013: 35-6). Was that an absurd action, or was it justified? The authors argue that precisely such evaluations are provided for in how the ontology of hot coffee is accomplished in accounts of the case. Characteristic of much of the media portrayal of the case is the following understanding:

> The apparent absurdity of the case stems from the common sense assumption that, after all, coffee is (surely) meant to be hot. If you opt to purchase a coffee (from MacDonalds), you might expect it to be hot and so should take all normal precautions when handling hot coffee. (Woolgar and Neyland, 2013: 35)

Such an account performs a particular moral order in the relations and contrasts it makes available. It simultaneously achieves an understanding of (1) hot coffee at MacDonalds as self-evidently what it is (*just* coffee); (2) normal people as those who know how to relate appropriately to the hotness of this (and any) coffee; and (3) people who see cause for holding a vendor accountable for serving hot coffee as 'absurd'. Accountability relations are thus articulated in relation to achieving the object at the centre of the case as perfectly mundane – evoking readers' agreement that this is indeed what everyone knows about coffee. However, the hotness of MacDonalds coffee is respecified in legal commentary on the case. In this respecification, the coffee "is no longer just hot, it is '30-50 degrees hotter than other restaurants', it is at a temperature that 'doctors testified…only takes 2-7 seconds to cause a third degree burn'," (Woolgar and Neyland, 2013: 36). The authors continue:

> By contrast with the initial common sensical reaction – how on earth could someone really try and sue McDonalds for providing hot coffee – the subsequent version achieves the kind of hotness of coffee for which McDonalds becomes appropriately accountable. The revised ontology of the coffee performs new accountability relations. (Woolgar and Neyland, 2013: 36)

This approach allows us to explore the awkward exchanges between the graders and the professor as a contest between two different ways of articulating both what numbers *are* and what the graders are supposed to do with them. In their reading out of the numbers on the screen, in the reticent way they respond to questions, in talking about "providing an overview", in "just keying them in", etc., graders display an orientation to the progress numbers as mundane and self-evident, as *just* counts of cases. This is not, of course, to say that counting is self-evident or unremarkable *per se* (see Martin and Lynch, 2012). It is to say that – in their actions to prepare for the meeting, in their performance in the meeting, and in their comments on these meetings – graders accomplish numbers as speaking for themselves, as needing no elaboration. The self-evidence of the progress numbers is achieved through the way the graders act towards them, and it reinforces the *rightness* of this way of acting towards them.

This is further outlined in the observation that the professor's critique of the graders' presentation – his holding them to account for improving what they present – involves challenging the achieved self-evidence of numbers as obviously and recognizably 'just counts'. Instead, the professor, in his response to the numbers, the questions he asks, the gestures he uses to lift out certain numbers, the requests he makes, his exasperation at not getting through, etc., orients to the graders' numbers as "just raw numbers". Note the different connotation the term 'just' has here, compared to the graders' enactment of numbers as 'just'

counts. In the professor's contestation of what the graders are doing, the numbers are characterized by what they are not-yet. These "raw" numbers are trends-to-be-realized. With this as reference point for "temporary imputations of moral orders of accountability", the graders' numbers are frustratingly non-insightful: they do not support the meeting's participants in making sense of where the project is at. Just as the lawsuit did for the hotness of the coffee, the professor's intervention challenges the accomplished ontology of the read-out numbers as 'just' counts. His way of acting towards the numbers draws on accomplishing their nature as not-yet-trends, which in turn reinforces the rightness of his critique of what he sees.

The achieved ontology of numbers is thus intimately implicated in the question of whether the professor's request to the graders is or is not reasonable. This is not a contest over what the numbers 'mean': what the professor does is not an ironic second-guessing, saying that what the numbers actually show is different from what graders suggest they show. It goes, instead, to the question of what a number properly should be taken to *be*. To illustrate this, we can point to the imputations of lack and excess that symmetrically characterize each party's response to the other's enactment of numbers. In the professor's orientation, the graders' numbers offer too little: 'raw' information, words floating in the air, marks deposited in a table, devoid of investment in how these can really be made to speak. In the graders' orientation, the professor asks for too much to be made of these numbers: the request is difficult to place ("we are not clear on what he wants"), hard to achieve ("this requires a lot of time and coordination"), even illegitimate ("we have to grade without bias"). In all these ways, the graders construe the request as something *over and above* the self-evident ways in which counting referral decisions and reporting on progress is part of their job.

What this analytic contributes, then, is a way of investigating what counts as accountable engaging in relation to how numbers are enacted as nothing more or less than what they are. The imputations of 'too little' (professor to graders) and 'too much' (graders to professor) show accountable engaging as the flipside of the accomplished ontologies of numbers.

Conclusion

By drawing together a fieldwork episode of a 'disconnect' in organizational work, and three STS analytics, this article has offered three ways of symmetrically describing varieties of accountable engagement with and of numbers. This question of 'engagement' is at the same time one of constituting numbers as what they *are*, and of detailing what those responsible for them can and should *do* with them. It is a question of what brings numbers alive, what sustains and secures them in their numberliness, and about the performance of organizational relations.

Helen Verran's (2001) work sensitized us to the multiple ways in which the numbers were done as a unity/plurality relation, a relation in which numbers become 'counts' or 'weightages', instantiated in ritualized repetitions that involve gestures and utterances. The professor's lively numbers specify engagement as a *whole/part* relation, one of percentage – thereby taking stock of progress by envisioning the project's trajectory into the future. But graders, to the professor's frustration, do not reckon with them in this way. They are doing numbers as a *one/many* relation, thereby taking stock of progress by adding up completed units of past work.

John Law's (1994) work sensitized us to the way numbers and appropriate behaviour towards them are delineated within different modes of ordering. In the mode of administration, 'correct-overview' numbers come to life in the following of procedure and avoidance of bias; in the mode of enterprise, 'drive-change' numbers come to life in the showing and telling of opportunity and threat in graders' orientation to both the project and their jobs. The professor wishes for *both* number-relationalities to be sustained, for numbers and graders to switch between one and the other. But graders stick with the mode of administration and do not sustain the 'drive-change' numbers beyond the professor's efforts at animating them in the meetings.

Steve Woolgar and Daniel Neyland's (2013) work sensitized us to how enactments of 'self-

evidence' become part of accountable engaging. The moral order made available in the professor's numbering features numbers as *needing to be probed and textured* so as to bring out trends and insights from inter-number relations and comparisons. By implication, the graders' numbers are 'raw', and graders' efforts in presenting them 'too little'. Conversely, the moral order made available in the graders' numbering features numbers as *needing to be left alone*: they are self-evidently what they are. By implication, the professor's request for different numbers is 'over and above', doing his bidding would involve treating numbers unaccountably.

What do we gain from this threefold sensitizing? Firstly, the symmetries produced in the threefold analysis show the graders' numbers to be 'proper' and alive in their own way, as a particular unity/plurality relation, within a particular mode of ordering, and in terms of a particular moral order. Graders may not be skilled with numbers in some ways, but they are in others. They sustain the lives of numbers in and through particular relations of respect, by accountably engaging according to what numbers' properties are taken to be. In three different ways, the graders' orientation to numbers has been rehabilitated, not by invalidating the professor's, but by telling stories of difference that are also stories of competence.

Secondly, we have charted a path into an empirical philosophy of numbers in STS that begins from the familiar strangeness of seemingly unanimated, 'floating' numbers. This is significant for making the question how *numerals* become *numbers* part of our repertoire. Empirical situations where parties are at odds over accountable engaging may touch on that very question, may instantiate it in number-relations as they are performed and contested. My hope is that the episode examined in this article will stand as one example of the possibilities of examining *already-made* numbers, in a field that methodologically has been drawn to studies of *numbers-in-the-making*. Perhaps this distinction is overblown: numbers-in-the-making are in another sense already pre-made (in the sense that they are conventional) and the showing, seeing, speaking and hearing of already-made numbers continues to 'make' them, as the threefold analysis above has shown. However, the familiar strangeness of numbers is given additional play by starting from the agnostic treatment of encounters in which the proper treatment as well as liveliness of numbers *qua* numbers is at stake. The three analytics sensitize us to the trails we can follow from such a starting point and could yield interesting analyses of other instances of demonstrations and presentations of number-forms, including engagements with (big) data (see also Nafus, 2014).

Thirdly, the abovementioned points can be taken forward in reflecting on the article's use and juxtaposition of STS analytics, in regard to the 'doing' of multiplicity, difference and contribution. The use of the analytics has multiplied the stories to be told of my fieldwork episode. Much in the way a kaleidoscope presents an ordering of its pieces that is different with each turn, each analytic organizes its symmetrical description according to a different concern, creating different patterns. For Verran, it is how (and with what consequences) the numberliness of numbers is manifested, for Law, it is how numbering co-constitutes the relations out of which organizational agency emerges, for Woolgar and Neyland, it relates to the conditions of possibility for treating numbers as self-evident. What can we do with such an observation? Rhetorically, in terms of how journal articles are often written, it feels difficult to leave things there, without a stronger statement of implications. Should I argue that it is only with Verran that the analysis is truly specific to numbers? Only with Law that the labour conditions under which the numbers emerge come into view? Only with Woolgar and Neyland that the lack of elaboration by the graders of their numbers turns from a lack into a constitutive element of the situation? Does this give us a basis to choose one over the others, in certain situations or for certain analytical purposes? Such a case could perhaps be made, but I would like to end on a note that leaves greater openness and that also, in parallel with lessons learned from STS analyses of numbers, shows greater regard for the work in and through which such analytics are sustained.

I say this in recognition of the fact that the episode 'works' the analytics as much as the analytics 'work' the episode – work that in each case produces relevant distinctions. The analytics

have produced graders' numbers as distinct from the professor's numbers by thickening what emerges as a disconnect in the meeting with ways of narrating relations of accountable engagement. Yet the episode, as a 'comparison engine' (Beaulieu et al., 2007) has also produced certain elements of the work of Verran, Law, and Woolgar and Neyland *as* number analytics that are *distinct* from one another, by enrolling them as tools on the 'same' job. Like the numbers they describe, the analytics have attracted labour (mine) to help coalesce and sustain them, and mull them over (see also Kenney, 2015). Again like the numbers, they become and remain things to be reckoned with in and through efforts to use them, respectfully and generatively. This acknowledges the creative intellectual work of furthering this particular corner of the STS field – work that entails doing empirical philosophy and wielding with precision the instruments we have available for doing it. It also suggests that we can commit to such work without the presumption of fully knowing, specifying, pinpointing, exhausting, or subordinating others' work *qua* analytics. With a capacity for surprise. The patterns and distinctions that show up in this way are worth noticing for the 'life' they contain and transmit. You may prefer one over the other, but the point is to have them show up in service of expanding and renewing our collective repertoires for how to think with what we encounter.

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Notes

1 Law cautions that modes of ordering do not stand outside their practical enactment; they may be usefully 'imputed' but have no driving force. In a later piece he adds that a mode or logic of ordering is meant to denote "a coherent and persistent feature of social relations. One test of that coherence would, I think, be their recursive propensity: that is, their tendency to reproduce themselves" (Law, 1996: 303, note 15).

2 https://www.mti.gov.sg/MTIInsights/Pages/Research-And-Development.aspx.

3 A telling example from the campaign to increase productivity is how one employee working in the housekeeping and linen management team of a hospital "realised that older workers sorting linen often had trouble differentiating one garment from another, so she made mini samples of each type of garment and put them up for easy reference to speed up sorting. Another seamstress working with her sews butterflies over small holes in hospital garments, reducing wastage. "It may be small, not big money, but the point is that we hope every employee, whether in cleaning, or the kitchen, or linen department will think about how to make things better and safer for patients," Mrs Chew [the CEO] says." (Teh, 2012: 11)

Adrian MacKenzie (2017) Archaeology of a Data Practice. Cambridge, MA: The MIT Press. 252 pages. ISBN: 978-1-5179-0064-9

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How can critical thought come to terms with knowledge practices fundamentally shaped by machine learning? What might critical thinkers learn from machine learners? And how could critical thought itself be transformed by engaging with digital data analytics? As machine learning – the programming of computers to learn from data – has spread across various domains and shapes knowledge practices in various fields, these questions are timely and pressing. To explore them, Adrian Mackenzie's pathway led him into *learning* machine learning: Combing through the vast corpus of machine learning literature, manuals and tutorials, using machine learning methods to analyse the references to machine learning in scientific literature, attending to the histories of some machine learners and following the proliferation and spread of others across various domains of knowledge, Mackenzie literally enacts what it entails to learn machine learning. While the subtitle of the book calls this approach an archaeology of a data practice, Mackenzie is not only digging deep into genealogies and ancestries of contemporary data methods, devices and infrastructures, but also dissects the very texture of machine learning and then weaves the various threads back together. Through this, he moves the reader through the central elements of machine learning that make up the seven empirical chapters of the book. To state this clearly at the beginning: large parts of the book are not an easy read (unless you are Paul Dourish maybe, who claims to have read the book on a flight from Los Angeles to Sydney). The book is populated with codes, tables, equations, graphic plots, list of references and is impressing with the synchronicity of engaging in the very practices that are observed. Attending to (seven) central facets of machine learning and various machine learners (human and non-human) Mackenzie carefully excavates some of the larger transformations and also smaller shifts that have emerged over the last decades in computer science, statistics, engineering and other scientific domains and especially across them.

The book left me puzzled in various ways. First and foremost, I was deeply impressed by the serious and deep engagement with the insides, technicalities and details of machine learning. Reading rather felt like a learning process itself where the teacher doesn't give you the answers but asks you to move along and explore yourself. In a sense, the book announces a beginning, an opening up of questions to examine further. It's the book you need to read to get an idea what questions to ask machine learners, assuming you want to go beyond familiar tropes of reductionism, lack of control and transparency, the risks of automation of knowledge production through machine learning. Those issues are still important and necessarily addressed, however Mackenzie gives us a clearer (yet more complicated) idea of where and how transformations are emerging and should be attended. Citing Foucault, Mackenzie insists, that "knowing the conditions, setting out the rules, and identifying the relations that striate the density and complexity of practice is a precon-

dition to any transformation in practice" (p. 217). And Mackenzie does exactly this, examining those preconditions.

The chapter *Diagramming Machines,* for example, unfolds the landscape of machine learning and thereby redraws the very frame of analysis. One of the sweeping developments in fields of machine learning has been the expansion and migration of devices and methods into various domains of science and industry. It is the diagrammatic formation of machine learners, their intersecting references and migratory pattern (beyond the common focus on "the algorithm"), which should catch our attention. With the diagram, which basically refers to a graphic description of abstraction in space, Mackenzie refers to both Foucault and Deleuze. As he explains in the glossary of the book "the diagram is a form of abstractions concerned with functioning and operations. In Gilles Deleuze's reading of Michel Foucault, diagrams display relations of force and construct models of truth" (p. 220) Most importantly, machine learners do not convey meaning in themselves (they are "a-signifying" in Deleuze's and Guattari's words), but generate ideas through bringing diverse fields into relation. A later chapter, *Regularizing and Materializing Objects*, convincingly illustrates the diagramming effects with the case of genome research: the scientific hyperobject "the genome" materializes and stabilizes through the specific entanglement of genetics, bioinformatics and machine learning, their data infrastructures, methods and devices, in unprecedented ways. Another central theme, which Mackenzie touches upon in different variations, is the question of abstraction and formalization generated by machine learning. While reduction and prediction might be central effects of processing data with machine learning methods, Mackenzie foregrounds multiplication and concretization. Much of the actual "learning" of machine learning, Mackenzie show us, is a constant, experimental effort in an unique entanglement of operation and observation. All along, Mackenzie's style is modest and cautious in the way he carefully points to transformations, never lapsing into polemic statements and hypes.

At the same time, and actually even for the same reasons, Mackenzie's Machine Learners also left me puzzled with a sense of frustration. The firm and detailed grounding of the analysis in the practices of machine learners is at times not only hard to comprehend and digest, but also left me with a strange feeling of boundedness, despite the many traces and movements outlined. In a sympathetic reading, I consider this a form of re-enactment of machine learners: their awkward indifference to the concrete settings where data are produced, the detachment of data from their messy groundings, the almost hermetic focus on inward processes of operation, observation and optimization, the seemingly indiscernible, tightly interwoven texture of links, iterations, expansion and trimming, regardless if the data at hand concern breast cancer research or the detection of cat images on the internet.

This analytic mode of re-enactment relates more generally to issues of immersion and intervention, of proximity and partiality with(in) research fields, which increasingly gain attention in STS and ethnographic research. In the preface, with the very first sentence, Mackenzie states, that even though "this book is not an ethnography, it has an ethnographic situation" (p. xi). However, in my understanding, the most powerful ethnographic effect is that it consists of something fundamentally more than a situation, it creates relations: in a way, it is always a distortion of a situation and thereby renders visible how things could be otherwise. There are und must be different ways to create such relations and irritations. Take Annelise Riles' twisting of *The Network Inside Out* (2001), where the network (of international human rights activists) was both her research object and she was an active part of it. How to study something which we are fundamentally part of? Another example, thematically closer to Mackenzie's book: Christopher Kelty's *Two Bits* (2008), which is simultaneously investigating and engaging with Free Software practices. In some ways Kelty's, Mackenzie's, and Riles' work are similar as they embrace proximity and immersion as the very strength of their analysis. Taking seriously the aesthetics of practices as object of analysis while taking part in it. Writing about code while writing code. However, Riles for example does purposely juxtapose and irritate this familiarity and thereby makes the contours

of the network appear in a figure-ground twist. What would a figure-ground twist of machine learners be? Or more generally, how could such an examination and description irritate and thereby create new relations? Mackenzie hints at some potentials for critical thought: we should ask how "divergence remains possible" (p. 102) despite the massive regularization and formalization of knowledge and how we might learn to experiment with prediction in the endless relays of reference provided by machine learning in a different way. Yet, those potentials remain mostly vague and almost vanish in light of the diagramming machinery. As stated above, the book's special feature is the generation of questions and potential pathways to be further explored. Overall, it provides supervised machine learning for critical thinkers, to enable them "to diagram a diagrammatic domain", as Mackenzie calls it (p. 207). As science, governance, industry, and many other domains are already fundamentally shaped by data practices, seeking for and tinkering with alternative ways of relating machine learners with elements of critical thought seems indispensable.

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Song Dongs's Exhibition 'Collaborations', 01.09-31.10.2017, Kunsthal Aarhus, Denmark

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In the fall of 2017 Kunsthal Aarhus presented the first "solo" exhibition in Denmark by the contemporary Chinese artist Song Dong. The non-monographic exhibition was entitled Collaborations – hence the quotation marks – and focused on collaborative forms. The title of the exhibition accentuates Song's strong interest in artistic collaborations – often involving members of his own family. On display was both some of the artist's best-known works and new creations. Song's work often focuses on family relations and geopolitics. They have a powerful way of expressing the effects of radical change and social transformation on members of his own family. He strives to combine the past and the present, the personal and the universal, the poetic and the political. Collaboratively. In Kunsthal Aarhus each gallery was dedicated to one chapter of Song Dong's artistic practice and collaborations, offering an overview of his diverse practice that embraces performance, installation, video and photography.

Entering the godinuniverse

In his interesting take on Donna Haraway's companion species, William Grassie explains Haraway's godinuniverse as:

> storytelling that we discover, invent, and share. godinuniverse includes stories about physical and biological relations, social and psychological relations, gender, class, and ethnic relations, family relations, sexual relations, economic relations, power relations, love relations, aesthetic relations, animal, plant and mineral relations. godinuniverse is a story about embodied semiotic relations that are causally significant in our thoughts and doings in ways both intimate and global.
> (Grassie, 2011: 9).

When best, engaging with Song Dong´s art feels like entering such a godinuniverse, including complex acts of kinship- and relation-makings. In this godinuniverse a multitude of relations are becoming. Relations between the artist himself and the vast number collaborators who participated in the realization of the exhibition. A (somewhat dim) attempt of creating a space for 'inter-visitorial' relation-makings, relations between architecture, consumerism and our digestive system. Relations between the inside of our homes and the surroundings outside. Interpersonal relations and not least the multifaceted, forever changing and often awkward family relations. The frailty and volatility of any such relations and relation-makings are made mercilessly present in a former piece entitled 'Stamping the water' (Performance in the Lhasa River, Tibet, 1996), in which the artist stood in freezing water and repeatedly stamped a large wooden seal bearing the Chinese character 'water' onto the ceaselessly flowing and disinterested river. Despite his audacity he failed to establish more than a fleeting relation to the water: "I exerted great force [in stamping the seal on the water], but in the end left no trace". (Jun et al., 2017: 22)

Outside

Next to the entrance of the museum Song erected an architectural structure commissioned by Kunsthal Aarhus entitled 'The centre of the world' (2017. See figure 1). The layout was based on the essential concept of a Chinese temple and contained sand from all of the time zones of the world. The collaborative collection of sand was made possible due to a number of embassies and individuals, who had brought sand from their home countries. According to the artist, the work positioned Aarhus at the centre of the world, but it also allured to an extended hospitality inviting people to a shared space, offering a platform for free speech and exchange of ideas.

While the collaborative idea of collecting and bringing together sand was intriguing, this piece felt very much like a rather high-pitched political concept, which only(?) worked 'on paper'. Following the grand opening the structure quickly 'dilapidated' into an extra bench area, where cigarettes were the primary objects of exchange. The piece lacked the sublime elegance found e.g., in the conceptually related work 'Socle du Monde' (1961) by Piero Monzoni.

Figure 1.

Inside

Inside Song's very popular and ongoing 'cake feast' entitled 'Eating the city' (2003-) initially occupied most of the museum hall (See figure 2). The piece was a large edible city modelled on the architecture of Aarhus. In collaboration with a group of local volunteers, Song built the city out of 90.000 biscuits, waffles and cakes. Previously he has suggested that the work is an exploration of mindless consumerism and the dramatic growth of hastily and carelessly build cities (particularly in Asia):

> Food is essential for humans, but biscuits - though they smell good and are sweet and cheap - are not helpful for the body. Biscuits are simple, like building materials, but they're bad things. Like these big, rapidly built cities (Alice, 2012: 1).

After the festive, but destructive "consumption" of the work on the opening night, the cake city was replaced by architectural structures built from Danish LEGO bricks by school children (See figure 2).

Here, the volunteers, the kids and the audience were invited into the collaborative process of both construction and 'demolition'. While the cake city was an impressive endeavor and had a charming, childish appeal to it, the installation as a whole came across as a bit 'gimmicky'. The urban theme found little resonance in a Danish setting. The white LEGO buildings seemed very Nordic: "[…] hart, abweisend und beständig wie skandinavischer Granit" (Fülberth et al., 2007: 140), but any

Figure 2.

resemblance to Aarhus or the consumed city was utterly lost in the translation.

Finally home

The center piece of the exhibition was the highly versatile work 'My Home is Your Stage' (2013-2017). At Kunsthal Aarhus Song Dong had erected a house (reaching 5 meters high and 11 meters long) built partly from material from his own house in China (See figure 3). The house structure mainly consisted of recycled window frames, revealing the interior space within and one gable was left open, but framed with classic red theatre drapes and dimly lit. The rooms end-wall was covered by a slightly distorted and irregular mirror (See figure 3). Guests were allowed to enter and 'use' the house and they could book it for meetings, events and the like (one couple even got married there (Petersen, 2017)).

The piece was captivating and worked on several levels! The title was indeed apt – the setting felt both like a stage and a staged home. The work challenged notions of borders between the private and the public by inviting visitors inside, into a *private* home, which at the same time was utterly *public*; publicly accessible and visually available to the naked eye. While the outside aesthetic was colourful - even joyful - the space somehow came across as eerie, way too open and transparent – a feeling enhanced by the mirroring wall. It was a home, but also a scenography decorated with an odd abundance of chairs and stools (retrieved from friends and neighbours) and a couch made by Song's wife and artistic collaborator Yin Xiuzhen (also on display in an adjacent gallery was their ongoing collaboration 'The Way of Chopsticks' (2006-)). The plethora of seats available added to the sense of a somehow displaced home (Christoffersen, 1996). The strong use of every modest household items resonates both with multiple other works by Song Dong and 'mundanity-invigorating' STS scholars like Steve Woolgar and Dan Neyland (E.g.: Woolgar, 2006; Woolgar and Neyland, 2013). The collaborative links were multiple; Close relatives like his wife, friends and neighbours, but also in-situ collaborations between Song Dong and the local performers utilizing the space at Kunsthal Aarhus. This multivalent piece effectively entangled both the past and the present and the personal and the universal.

Here, the bystanding statue of police officer complicated the notion of home and privacy. However, here it was a series of sixteen life-size statues of law enforcement officers (Policemen, 2000-2004), each bearing the artist's visage, which were "casually" scattered around the museum. Standing by doors or in restrooms they are both eerie in their personalized uniformity and their unnatural presence. They confronted the defenseless viewers and reminded us of our own mental policing and the difficult relations of self-governance.

Getting personal

Keeping with the personal feature; The exhibition in the basement of Kunsthal Aarhus centred on close relational collaborations. This section showcased a series of works relating to personal stories of Song Dong and his family-members: '36 calendars' (2012-13), 'My Daughter is My Four Seasons' (2010), 'Touching My Father' (1997-2011) and a large-scale photo documentation of one of his best-known works 'Waste Not' (2005), which shows the artist's mother's house with all her belongings. Also on display was a film co-

Figure 3.


Figure 4.

authored by Song and his daughter Song Errui entitled '50+14' (2017). Of the personal works - 'Touching My Father' packed the biggest punch, not least due to the very touching work-description supplied by Song Dong. The work consisted of a short video of his (now dead) father. While shooting the video, Song had superimposed a golden – almost radiant – picture of his own hand stroking his father. The interplay between the otherwise physically reserved and "untouchable" father and the gentle strokes was both touching and emotionally difficult to hold. A very delicate 'touch-non-touch' strategy embracing both Chinese cultural-history and the need for personal intimacy. 'Waste Not' (2005) was an installation of the full complement of worldly goods belonging to the artist's mother, Zhao Xiangyuan (1938–2009) - including the wood frame of her house. Song's mother was typical of the generation of Chinese who lived through the hardships of the Cultural Revolution in the 1960s and 1970s abiding by the dictum *wu jin qi yong* (waste not). This guiding tenet deemed that resources be squeezed for all their value and nothing be wasted. For the subsequent generation - Song Dong and his sister, Song Hui, among them - the result was a childhood surrounded by partially used bars of soap, loose buttons, assorted buckets, and scraps of fabric, stockpiled and preserved as protection against future hardship, even in the face of improving economic conditions (MOMA, 2009).

The large photographs of the famous work functioned as a nice memorandum, but lacked the overwhelming dense presence of the actual work – displayed at Kunsthallen back in 2014 (See figure 4). Less personally connected, but quite captivating was the extensive piece '100 Years' (2010) consisting of 100 black and white re-paintings of historic paintings coupled with 100 historic events. The pairings deliberately disregarded any obvious connections or concordances like time or theme, thus rendering all sorts of (made up) links and intriguing speculations possible.

While leaving Kunsthal Aarhus I feel an urge to revisit my godinuniverse. Here, I find both 'Song Dongian water stamps' of fleeting impact, but also new radiant and durable relations.

About the artist

Song Dong is a Chinese artist, born in 1966. He lives and works in Beijing. Song comes from a strong Chinese avant-garde performing arts community and developed into a major contemporary art figure in the progression of Chinese conceptual art. He has been considered at the forefront of Conceptual art in China since the 1990's. Song graduated from the Fine Arts department of Capital Normal University in Beijing in 1989. His practice embraces performance, installation, video and photography. Recent major exhibitions include venues as: 5th Moscow Biennale of Contemporary Art (2013), Carriageworks, Sydney (2013), Barbican Art Gallery, London (2012), dOCUMENTA (13), Kassel (2012), Venice Biennale (2011), The 6th Liverpool Biennial (2010) and MoMA Museum of Modern Art, New York (2009). Song was awarded a UNESCO/ASCHBERG Bursary Laureate in 2000 and won the Grand Award at the Gwanju Biennale in South Korea in 2006.

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Notes

1 E.g. 'The Way of Chopsticks' (2001) – also on display – 'Surplus Value' (2016), and his best-known work 'Waste Not' (2005).

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