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Investigating materiality for a renewed focus on data practice through design

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Abstract: This paper attempts to question reductionist processes of data science that help sustain digital economies and proposes a new perspective for *data practice through design*. It follows recent discussions about the materiality of data in design and proposes a new notion of data materiality that unfolds its ethical and ecological aspects from a philosophical point of view. This is presented as an opportunity to envision how data can be enacted as data practice within a system. We provide an example that illustrates different kinds of data and data practices, and how ethical and ecological challenges can emerge in a system. We show how systemic challenges can be alleviated within this new notion of data, demonstrating why recovering data materiality is crucial for an ecological future. We finally argue that designers play a significant role in this context, producing practical examples that extend theoretical discussions on data materiality.

Keywords: materiality; becoming data; data practice through design; systems thinking

1. Introduction

Data systems have become a powerful necessity of modern digital societies. Data systems have been continuously optimised to maintain the global economy in what can be seen as attempts to reduce time and space boundaries (Virilio, 2000). Data has become ubiquitous with better transmission, storage and reuse, and data science has worked to improve ways to optimise what takes place, and predict what is yet to occur, detaching data from instances in the natural world (Kitchin, 2013).

In the natural world, living and nonliving things keep evolving and changing at every moment according to contextual relationships, and so is the data that is embodied by them. In contrast, current concepts of data are fixed, independent and represented by cutting off contextual relationships (Leonelli and Tempini, 2020). By attempting to transform things into simple data representations, current data systems fail to contain the spirits, relations and interdependence of living and nonliving things in the world.

In his 2017 paper 'Data Science as Machinic Neoplatonism', McQuillan uses Barad's theoretical framework for Agential Realism to detail the limitations of the contemporary form of data science that underpins so many of society's data systems. Central to Barad's work is her own experience through theoretical physics and in particular quantum physics in which she observes how the representational principles of Newtonian and Cartesian sciences fail to explain phenomena at a subatomic level. Citing the experiments of Neils Bohr that revealed the significance of the scientific observer's presence upon anything that is observed, Barad builds a thesis that dismantles the power of representational ways of knowing the world. McQuillan picks up the argument and extends it to data science. McQuillan's argument is that the maths underpinning data science enables a position from which to represent and quantify the world by remaining outside of it (as Newtonian and Cartesian models do) — a position of power that succeeds in making untenable social and economic promises to and for the world (McQuillan 2017).

McQuillan continues to explore the deterministic characteristics of data science by detailing the so-called economic imperatives that 'pay' for the technology's development. By explaining the implications of the opacity of AI based systems that deploy data science to offer a 'predictive power', McQuillan points to the biases that have emerged over recent years as industry has rushed to adopt technologies that promise to improve their business models. Attractive because they promise an ability to analyse large and complex data sets, the outcomes of the data-driven processes are loaded with biases and lead to discriminatory futures. Examples include the prediction algorithms that select entry into healthcare programmes and exhibit a bias against African-American patients (Obermeyer et al 2019), or gender discriminatory recruitment tools used by Amazon (Dastin 2018).

While design and HCI researchers have discussed materiality as a way to enhance interaction and understanding of data, in this paper, materiality is approached with a focus on the nature of being a material, which has a physical body, and creates capacities and constraints by ongoing 'intra-acting' — "in contrast to the usual interaction, which presumes the prior existence of independent entities" (Barad, 2018). Through this paper, we are particularly interested in the intra-actions across biological, social and cultural contexts. For example, in the natural world, a tomato seed continually 'intra-acts' with the world and this ongoing intra-action between the seed and its circumstances allows for the development of a diverse variety of tomatoes. Data systems in contrast obfuscate the complexity of relational aspects of the world in order to make simple and reproducible systems composed of partial elements of nature such as specific genetic codes, the amount of energy (kWh) necessary to grow a tomato, amount of water (L), temperature (°C), etc., which will be translated into a specific number of tomatoes of specific weight (kg), that will be translated into predictable sales and profits (£).

The global economy heavily relies on these relatively linear data systems that can be measured and therefore predicted to improve productivity and efficiency for economic growth. This economic growth, however, does not count ecological boundaries and limitations (Raworth, 2017). Citizens, industries and governments are blinded from perceiving living things and the environment beyond the quantifiable, by being presented data in quantitative ways, while missing its richness and complexity in the physical world, which, we argue, is fundamental for human and more-than-human survival.

In this paper, we aim to articulate the limitations and challenges of the current notion of data and propose a new way of understanding data from a system perspective. This new proposition brings three contributions to the design field. First, it shows a tangible way to understand data materiality in a system. Second, it provides criteria to tackle data materiality at the beginning of data processes in practice. Third, it stresses the importance of the designers' role in drawing attention to data materiality when they design a data system. In this way, it offers a broader understanding of what we call *data practice through design* which can contribute to wider perspectives of our shared ecological futures.

2. Discussions about data materiality in the design field

A growing number of designers and HCI researchers have adapted the notion of materiality to utilise it in design practice (Offenhuber, 2020; Berzowska et al., 2019; Giaccardi & Karana, 2015; Wiberg et al., 2013, Tholander et al., 2012). Their approaches tend towards two directions: 1) interaction with materials of design practice/computational materials and 2) data physicalisation/physical aspects of data.

2.1 Materiality of design and HCI practice

The first approach focuses on the materiality of design and HCI practice (e.g., the materiality of things or the interaction with things). For decades, the tangible and embedded interaction movement initiated by Ishii's tangible user interface principles (Ishii, 2008) has attempted to investigate ways of enhancing material and embodied aspects of computer systems. More recently, Wiberg et al. (2013) attempted to "conceptualise the computational based on its properties and how, through their arrangement, they entangle with social practices in different ways, revealing particularities, surfaces, and temporal flows". Other frameworks and tools have been introduced to adapt the concepts in practice (Berzowska et al., 2019, Giaccardi & Karana, 2015, Tholander et al., 2012). These vital approaches have explored new materials for interfaces, experiences and interactions. Their focus of materiality, however, is on implementing existing or developing interfaces and interactions of predetermined things within the stable and same value system that we consider problematic for unfolding ecological challenges that are variable in different contexts.

2.2 Data physicality

There is a growing movement that looks at ways to produce physical representations of data, or data physicalisation (Jansen et al, 2015). Offenhuber (2020) looked to extend this movement by drawing attention to how data physicalisation can engage social and cultural contexts. He argues that, more than replacing the digital with physical materials to give textures and volumes to traditional data representation, data physicalisation could become a practice to re-engage properties of things and contextual relationships beyond digital data (e.g., to increase environmental awareness, an artist selects plastics as data and installs a material diagram on the beach where the plastics are collected, this contextual information would help the audience understand why they should use fewer plastics to protect the environment). Despite coming from a different perspective, Offenhubers's paper indicates the potential of looking into social and cultural relationships with material data.

Overall, within this strand of research, authors mainly dispute material qualities and properties at an object/material scale. In contrast, we aim to approach it through a system perspective and wider scale, as discussed below.

3. From material data to data practice

For decades, philosophers and social scientists have taken a deep dive into the understanding of materiality ontologically (Haraway, 1997; Latour, 2005; Barad, 2007; Suchman, 2012). It is followed by discussions about the importance of utilizing the theoretical understanding of materiality in data and data practice (Leonelli and Tempini, 2020).

Here we argue that understanding data materiality within a system can help to embrace the complexity of contextual relationships and illustrate the importance of applying practice-led methodologies. To further the understanding of the potential of ethical and ecological implications, we propose a way to reframe the notion of data within an economic system (e.g., food system), which can engage practitioners, industries and governments to take actions for the ecological impact at diverse levels of the system.

In this section, we dive into the notion of materiality from Barad, Suchman, and Haraway and observe how a new type of data practice can be enacted in data systems through the Data Journey methodology.

3.1 From material things to phenomena, the world's becoming

Latour (2005) emphasises the presence of networks of relationships by mentioning that nothing exists outside social and natural relationships. Connecting to his argument, humanities and social scholars such as Barad, Suchman, and Haraway have talked about how relationships are enacted with the materiality of things and why we need to pay attention to 'phenomena' involving the whole complexity of things and their relationships. They stress that materiality does not end in/between things but rather extends to the ecological mess, uncertainty and complexity via 'intra-actions', configurations, networks, and assemblages.

According to Barad (2018), things (i.e., humans and nonhumans) iteratively configure boundaries through 'intra-actions' and she defines the dynamic configuration processes as phenomena. For understanding the complexity of the world, she asserts we need to focus on "the primary units that are not words (things) units but material-discursive practices through which boundaries are constituted". Her concepts induce us to move our attention to doing/being of intra-activity to intervene in the material world's 'becoming'.

Suchman (2012) describes that 'configuration' brings things together – "at once reiterating the separate existence of the elements assembled, and drawing the boundaries of new artefacts". She shows a possibility to use configuration, one of the substantial points of materiality, as a tool to study technologies that bring digital-material relationships for designing socio-technical systems.

Haraway further introduces the notion of 'diffraction':

> "What we need is to make a difference in material-semiotic apparatuses, to diffract the rays of technoscience so that we get more promising interference patterns on the recording films of our lives and bodies. *Diffraction* is an optical metaphor for the effort to make a difference in the world. . . . *Diffraction* patterns record the history of interaction, interference, reinforcement, difference. *Diffraction* is about heterogeneous history, not about originals. Unlike reflections, *diffractions* do not displace the same elsewhere, in more or less distorted form." (Haraway, 1997, in: Barad, 2007, p. 71)

Barad follows up Haraway's metaphor of 'diffraction' as a thinking tool that helps us criticise current reflective approaches and contemplate visible ways to intervene in the world's 'phenomenon' —its intra-active becoming. From her following statement, we can understand how the whole discussion started from materiality leads to ecological awareness of humanity:

> "The point is not simply to put the observer or knower back in the world (as if the world were a container and we needed merely to acknowledge our situatedness in it) but to understand and take account of the fact that *we too are part of the world's differential becoming.*" (Barad, 2007, p.91)

3.2 Practices of data

Leonelli and Tempini (2020) illustrate a relational view of data and how we can adopt the view to tackle data-driven systems through the Data Journey methodology. Leonelli (2016) asserts that it is 'data travel' for producers, curators, and users continuously making decisions about what constitutes data in relation to the changing circumstances and aims of each stage of a data journey. The authors delineate not only 'data' but also data 'practice' and implicate theoretical limits (materiality) in practice (data practice).

In 'Data Journeys in the Sciences', Leonelli and Tempini (2020) introduce the term 'lineages' as a new perspective of data as it allows us to challenge existing data practices (i.e., mapping, analysing and comparing the production, movement and use of data). Like lineages, data is evolving by responding to ongoing intra-active causality in data practices:

> "The relational view of data makes them into historical entities which – much like organic beings – evolve and change as their life unfolds and merges with elements of their environment. Building on this biological metaphor, I propose to conceptualise data as *lineages*: not static objects whose significance and evidential value are fixed, but objects that need to be transformed in order to travel and be re-used for new goals." (Leonelli and Tempini, 2020, p.7)

From their exploration, we can acknowledge that the general notion of practice has a different focus from the material-discursive practices that Barad talks about. The way we often understand data systems is as designed by/for humans, humans are therefore seen as the main decision-makers for mapping, analysing and comparing data in practice. That is why Leonelli and Tempini compare different data practices across biological, biomedical, environmental, physical and social sciences and share coherent methodological insight on how humans (i.e., scientists and engineers) can intervene in ecological challenges of data-driven systems with the relational view of data.

Data journeys as a practical methodology encourage us to pay attention to data practices embedding data that are situated, evolving, and contextual and collaborate with experts from diverse disciplines and practitioners who are familiar with each step of journeys. We can witness that data practices in the methodological journeys require new skills and mindset to embrace uncertainty and complexity from flows of data, and deal with specific and local moments and situations with specific human collaborations. In that sense, the emerging qualities of data practices become similar to the nature of design practices.

3.3 Becoming data and data practice through design

Based on the philosophical understandings above, we present two new definitions of data and data practice that are essential for our methodology.

Becoming data is considered here as evidence/impact of phenomena or differences in phenomena that are the whole complexity of things (i.e., material and digital, human and machine, living and non-living) and their intra-actions in a specific stage within/between data system.

Data practice through design is the proposed skills and mindset grounded in design practice to embrace ecological uncertainty and complexity of data, people and the world.

We aim to introduce *becoming data* (e.g., instead of data lineage) as a new notion of data. Our intention places greater emphasis upon a *data practice through design* that supports the emergence of phenomena and helps us navigate differences between phenomena, rather than a data science of things that become classified and isolated from the world. Furthermore, we prefer using *data practice through design* to data practice, as this allows us to emphasise the limitations of current data practices and the opportunities for designers to challenge the complex world (Stolterman, 2008).

4. Data practice through design within a food system

In this section, we bring a tangible example to help readers to understand the ideas and summarise differences between data science and what we call *data practice through design* in a final table.

4.1 Tomato seeds and a food system

In 'Small Arcs of Larger Cities', Bateson (2016) provides a poetic description of 'seeds' and 'food':

> "Seeds are not only beginnings, they are *witnesses and referees* to evolution. They are immigrants, hitchhiking with the cultural fusions that migrations of animals and peoples make. Taking their bread with them. Taking grandma's recipes. Seeds get caught in your fur if you are a wolf, and take a whole winter to run through the digestion of a bear…. Food is agriculture, economy, culture, and conversation, ancestral recipes, weavers of tablecloths, traditions of seasons, the perfect onion, a child's berry-stained chin…. Ask the question 'What is food?'—and the answer is not 'the stuff on my plate.' The answer is that food is about *relationships*... Seeds used in ceremony represent long-term linkages between people, nature, cycles, and attitudes toward the future." (p.31)

In her text, seeds and food are illustrated as 'witnesses and referees' and 'relationships' to describe their roles in linking people, nature and the worlds' becoming across phenomena. Her narratives about seeds and food inspire us to show how to trace the impact of differences resulting in consistent phenomenal intra-actions in the world's becoming. With inspiration from her texts, we harness seeds and food analogy as a methodology to envision how *data practice through design* tackles ecological challenges and opportunities in a system. To see how seeds and food as *becoming data* enact *data practice through design* socially and environmentally, we pay attention to a conventional food system.

Let us investigate the process of ketchup production, part of the global food economy, to be more specific. Tomato seeds are transformed into tomato plants to grow tomatoes in natural or managed settings. The harvested tomatoes are processed and packaged to become ketchup products in a factory. Ketchup products are then distributed to global markets and reach customers' tables. In the transition from tomato seeds to ketchup products, social, political and environmental contexts that influence the supply of the product are obfuscated from the 'consumers' sight, reducing apparent friction, and prioritising value according to an affordable price.

Food providers have invested in data systems to re-enact the best condition for maximizing tomato yields, consistency of ketchup quality, stabilizing stock and logistics, increasing market share and profit globally. Such systems are designed to mitigate against the complexity and uncertainty of the world to retain a stable perception of the product, methods that rely upon the use of data to inform statistical models and control the outcome. Temperature, water and energy consumption, soil composition, ketchup viscosity, automation rate, product loss, product shelf-life, product revenue and cost, consumers' buying patterns are all selective forms of data that increase the likelihood of delivering a consistent product. Global food companies such as Kraft Heinz (Just Food, 2020), actively collaborate with IT companies such as IBM and Microsoft to provide analysis and prediction through big data at all steps within their industrial lifecycle.

When we see the conventional food system from a data perspective, two entangled cycles emerge that are supported by data systems that span production to consumption: the biological cycle and the technical cycle. According to 'Cradle to Cradle' (Braungart and McDonough, 2009), the biological cycle relates to living things within complex ecosystems, while the technical cycle is associated with artefacts feeding into the industry. For a long time, our economy has prioritised the need to develop resilient industrial lifecycles and has used data science to improve the performance and efficiency of production. It has led to modifying biological elements artificially to feed into the technical cycle, including the creation of GMO tomatoes for commercialisation. However, we need to remember where all raw materials come from to produce ketchup: seeds, water, energy, materials for factory buildings, packages, transportation, data centers, locations and humans. All come from the earth and are interconnected with their own biological cycles. We need new data systems that include biological cycles so that the complexity and uncertainty of environments can be accounted for and protected against to limit the world from climate change and resource scarcity (Raworth, 2017).

As designers, how can we design data systems that better balance biological cycles and technical cycles? What would it look like if we adopt the concept of *becoming data* to envision new data systems and create the criteria of *data practice through design*?

First, we need data systems that envelope far more of the social and environmental ecosystems across which data is captured to better anticipate *becoming data*. In this case, *becoming data* is tomato seeds and tomatoes. Tomato seeds themselves cannot grow into plants and bear tomatoes as fruit. All dynamic intra-actions between the seeds, all living and non-living things (e.g., soil, the weather, insects and so on) support the growth of tomato plants, and the bearing of tomatoes. The intra-actions are continued for ripening tomatoes and carrying tomato seeds in the tomatoes. Tomato seeds and tomatoes are genuine evidence of the phenomena. At present data-driven technical cycles can be understood to intercept these biological cycles and manage highly selective and extractive intra-actions to ensure the production of limited (but perfectly formed) ketchup. A more expansive *data practice through design* would support the inclusion of many more social, environmental, cultural and economic datasets to anticipate sustainable intra-actions with tomatoes.

Second, we can try reconstructing contextual relationships and entities of every moment of *becoming data* transformation (e.g., germinating, growing, getting tomatoes, moving, modified, processed and so on) toward the making of ketchup. From a wider ecological perspective, the many parts of the tomato plant, from its roots, stems, leaves and flowers continuously intra-act with the inner environment of the greenhouse to absorb nutrients and moisture and breath. In addition, the greenhouse utilises energy (often electricity) to control the inner condition such as humidity, lighting, ventilation, CO_2 level, temperature, irrigation and fertigation while discharging light, air and water pollution to the earth. A true contextual perspective would encompass the wider relationships across which energy is derived, from extraction to exchange, allowing a *data practice through design* to understand the extended impact of a bottle of ketchup (e.g., pollution, exploitation).

The goal of *data practice through design* is to keep raising questions toward *becoming data*. The questions let us realise the relational nature of a world that is complex and messy and accept that a data science approach to capturing knowledge is extremely limited. In order to respond to the world's becoming, the designers' task is to tackle our data systems with these questions connecting context to context. Here, tackling data systems can be interpreted as reconfiguration, revitalisation and refinement toward nature. To embrace the unpredictable emergence, *data practice through design* trains designers to learn to stay present.

> "In fact, staying with the trouble requires learning to be truly present, not as a vanishing pivot between awful or edenic pasts and apocalyptic or salvific futures, but as mortal critters entwined in myriad unfinished configurations of places, times, matters, meanings." (Haraway, 2016, p.1)

4.2 Comparison of data science and data practice through design

We have discussed how *data practice through design* can lead us to ethical, social, political and ecological matters, unlike data science. To show the differences between *data practice through design* and data science approaches, we explain their conflicting propensities as shown in Table 1. The table aims to support critical and creative perspectives in design to recover ethical and ecological aspects of data systems. In the table, situated knowledge is drawn from Haraway (1988), who uses the term to emphasise an embodied and located subject, and a contextually and historically specific perspective to create knowledge.

Table 1 Comparison of Data Science and Data Practice through Design.

Data science	**Data practice through design**
Representative	Relational
Connected	Entangled
Pre-existing	Emerging
Endless	Birth and Death
Improving	Evolving
Scientific knowledge	Situated knowledge

General	Local
Predicting	Observing
Reducing complexity	Embracing complexity
Controlling	Responding
Focusing on sameness	Focusing on difference
Process	Flow
Analytical approach	Systemic approach
Distancing from the world	Being part of the world

5. Conclusion

This paper has interrogated the challenges and limitations of data science and articulates a new way for encompassing ethical and ecological elements of the world in data systems.

Design and HCI scholars have recently started to look beyond a distinction between the physical and the digital, attending to emerging matters from digital-material relationships and processes in our experiences, activities and environments. In his recent paper, Frauenberger (2020) insists that we stand at "the beginning of the next paradigm shift in HCI as the existing practices and theories are starting to show conceptional shortcomings in describing and conceptualising the changes we see in our relationship with digital artefacts". We contribute to this discussion by looking at how design and HCI's practice-led approaches can adopt the theoretical frameworks and the notion of materiality grounded in Agential Realism.

We suggest that current data science approaches rarely attempt to 'stay with' the uncertainty and complexity of phenomena entailed in systems thinking. We propose the notions of *becoming data* and *data practice through design* to support not only academic researchers but also practitioners, business decision-makers and governments to review their business and policy models for an ethical and ecological perspective, and design interventions through collaborations with different stakeholders at various levels and stages of a system. The paper calls for an opportunity for designers to consider how to readdress data systems (e.g., in food and healthcare fields) and how a *becoming data* approach can include participant entities beyond humans and economic systems, looking at benefits for plants, animals and the geological world.

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